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JANUARY 5, 1887.

COMMANDER WM. T. SAMPSON, U. S. N., Vice-President U. S. N. I., in the Chair.

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The meeting was called to order at 8 P. M., and the chairman requested the Secretary to read the paper before the Institute.

Lieutenant JNO. W. DANENHOWER.—*Mr. Chairman and Gentlemen:*—I desire to state before reading this paper that it originated by invitation of the Institute, for the purpose of producing a profitable discussion on the subject of Steel for Heavy Guns. About one hundred and fifty corrected galley-proofs of the paper were sent to the friends and supporters of the author, as well as to other steel manufacturers and ordnance experts who were invited to be present or to communicate their views. The author is a well-known member of the American Society of Civil Engineers and of the American Institute of Mining Engineers, who has devoted much time to the subject of steel for structural purposes. I regret extremely that he is unable to be present at this meeting, for his personality and the earnestness of his convictions would add great force to his paper.

# STEEL FOR HEAVY GUNS.

By Edward Bates Dorsey, C. E.

During the last four years I have been obliged for professional purposes to examine as thoroughly as possible into the suitability of steel for structural purposes. This investigation obliged me to make several trips to Europe, as I was anxious to get the opinion and experience of all the principal steel workers of the world.

The word "steel" as used now is very comprehensive, embracing material running from a very pure quality of iron, with little or no carbon and a tensile strength of 55,000 pounds, up to tool steel with a high percentage of carbon and a tensile strength of over 150,000 pounds. In this paper, for convenience, I shall use the terms "mild steel" and "hard steel" with the following meanings:

Mild steel is steel with a very low percentage of carbon, incapable of taking temper; will bend double, when cold, without fracture, and having a tensile strength of from 55,000 to 65,000 pounds.

Hard steel is steel with a variable percentage of carbon; will take temper, more or less hard, and having a tensile strength of over 90,000 pounds.

Tensile strength, whenever used in this paper, will mean, unless otherwise stated, the ultimate tensile strength per square inch of section in pounds.

All workers in steel will admit the following axioms to be true and indisputable: 1st. The treacherous and capricious qualities of steel increase with its tensile strength, being zero about 60,000 pounds tensile strength. 2d. The treacherous and capricious qualities of steel increase as the size, thickness or section of piece increases. 3d. The greatest reduction of size, thickness or section by work within limits will give the greatest increased tensile strength. 4th. With the same amount of work within limits, the tensile strength decreases as the size, thickness or section increases.

Mild steel is the most reliable of all cheap metals. It can be badly worked and maltreated with impunity, yet it can be trusted under all circumstances. Hard steel, on the contrary, requires the most delicate manipulation, and even then it will, when in large pieces, break and crack without any apparent cause or reason. In all shops

that have worked large-sized pieces of it, there are told many stories of how it cracked when it was completely at rest, etc. This has been proved by the recent failures of the steel guns in England, all failing under little or no strain.

Gunmakers are now apparently committing the same errors that civil engineers did when they first commenced to use steel for structural purposes. They found a new, cheap and strong metal, but their use of high-tensile-strength steel temporarily brought this material into disrepute. Nearly all failures in its use can be ascribed to this cause.

The specifications of the Ordnance Office of the War Department ask for bids for hoops for eight-inch guns, the maximum thickness being $4\frac{9}{16}$ inches. (The promised specifications from the Ordnance Office of the Navy Department have not been received.) These specifications call for tensile strength not less than 100,000 pounds per square inch; elongation after rupture not less than 12 per centum in specimens six inches in length between shoulders; all to be of open-hearth steel.

Without the oil temper this quality of hard steel would not be used by any bridgebuilder, boilermaker, shipbuilder, or architect where the strain or work is comparatively steady and regular compared to the heavy, sudden shocks caused by the service charge of powder in large guns. As yet, the experiments showing the actual *improvement* on hard steel by the oil temper in large pieces* or masses are not sufficiently thorough or complete to be conclusive, or to induce the general use of an unreliable material. The advocates of the use of hard steel claim that it is much improved and its nature and character entirely changed by immersion while hot in an oil bath. Unquestionably this has a very beneficial effect upon small pieces. Hard steel is one of the most compact of all known

* The circular from the United States Navy Department of August 21, 1886, inviting bids for gun forgings, does not give the dimensions; it, however, gives the approximate weight as follows:

"These forgings are to be delivered rough bored and turned, and when in that state the heaviest forging which enters into the construction of a gun of each of the desired calibres will be about as follows:

| | |
|---|---|
| 6-inch . . . . | 3¼ tons. |
| 8-inch . . . . | 5 tons. |
| 10-inch . . . . | 9½ tons. |
| 10½-inch . . . . | 9¾ tons. |
| 12-inch . . . . | 12½ tons." |

substances. Can the oil of the bath or its good effect penetrate sufficiently far into the interior of this compact material in large masses so as to make a complete change in its character? May not the beneficial effect shown be only on or near the surface—skin-deep?

In my judgment, the great improvements reported in the working qualities of hard steel caused by the oil bath on large pieces have not been conclusively demonstrated, especially in face of the recent failures in large steel guns. On the contrary, do not these failures show that hard steel still retains its character unchanged for capriciousness and unreliability? Before spending the millions of dollars for new guns for our Army and Navy, it would be well to test more thoroughly the supposed great improvement made in the character of large masses of hard steel by the immersion in the oil bath. There is no question but that hard steel is entirely too unreliable to be used in its natural state in large pieces for any kind of structural work. These tests and experiments should show conclusively that the oil temper changes a structural material unsafe for the most simple work into material reliable for the most trying and difficult service. If these experiments do not show this beyond question, then hard steel should not be used for the large guns.

The *Lloyds' Register* of England have probably more practical knowledge of steel than any person, firm, or corporation. Mr. Parker, their chief engineer, who has been a most indefatigable experimenter and investigator in steel, was among the first to advise its use in marine architecture, especially for boilers. Notwithstanding their long experience, the following order was issued last month: "The Committee of Lloyds' Registry for British and Foreign Shipping, having been advised by their technical engineering staff that it was fitting that there should be greater stringency as to the tests to which steel for boilers is subjected, have issued modified instructions on the subject. Formerly all steel for boiler plates was required to have an ultimate strength of not less than 26 (long) tons nor more than 30 tons per square inch of section, with an ultimate elongation of not less than 20 per cent. in a length of eight inches. In the matter of elongation their requirements remain the same, but as regards the breaking strain a sliding scale is adopted as follows: The material of stays and of plates not exceeding 1 inch in thickness is to have an ultimate tensile strength of not less than 26 and not more than 30 tons per square inch of section; in plates above 1 inch and not more than 1¼ inches in thickness, the ultimate strength must not be less

than 26 and not more than 29 tons per square inch, and in plates above 1⅛ inches in thickness, not less than 26 tons and not more than 28 tons per square inch." Here we have the most experienced body in the world reducing the tensile strength proportionally as the thickness increases, in order to get good, reliable metal for boilers. We, however, increased largely the tensile strength with the thickness in our gun metal. These two practices are very different; which is right?

The preceding statement, analyzed, shows thus:

Plates and stays 0 to 1 inch thick, maximum tensile strength 67,200 pounds.

Plates and stays 1 to 1⅛ inches thick, maximum tensile strength 64,960 pounds.

Plates and stays over 1⅛ inches thick, maximum tensile strength 62,720 pounds.

If the same proportion should be extended to a plate 3 inches thick, the maximum tensile strength would be 55,052 pounds.

As it is impossible to work exactly to the minimum and maximum limits, practically the specifications for guns are *double what is considered safe for boilers.*

The Duke of Cambridge, Commander-in-Chief of the British Army, said in the House of Lords on April 30, 1876: "Out of seventy heavy guns employed against the southwest of Paris (by the Germans), thirty-six were disabled during the first fortnight of the bombardment by the effect of their own fire." This is strong language from very high authority, and shows that even Krupp's guns may fail when tested by actual service. The preceding also shows the great necessity of a thorough investigation before a final determination on this subject.

All who have worked large pieces of hard steel have noticed that serious cracks and fractures originate in very slight cuts, nicks or punctures in the metal; in fact, on this class of metal all such injuries are carefully avoided, and when they unavoidably occur are, if possible, carefully cut out. In working hard steel, in order to prevent the starting of these cracks, no holes are punched unless carefully reamed out afterwards, and no edges cut or sheared unless afterwards planed. Mild steel is not affected in this manner.

In battle these large guns must receive many dents or cuts from shot from small cannons and machine guns. These injuries may not be sufficiently large to cause direct weakness of the gun, but they are

ample to originate the fatal cracks so common and unaccountable in hard steel. The formation of these cracks will be accelerated by the firing of the heavy-service or fighting charge of the gun. Of course, if the gun is entirely protected from the fire of small cannon or machine guns, this risk will be avoided; but, owing to the great length of modern guns, it is doubtful if its entire length can be protected from machine-gun fire. Before finally adopting this class of metal for our large guns, it would be well to make experiments, to see how guns made from it would act under the same conditions as in battle. They should be subjected to a severe fire from small cannon and machine guns, and afterwards fired repeatedly with the usual severe fighting charge.

## Conclusions.

If it is necessary or desirable to have light guns, these can be made by using many thin hoops, or cylinders, made of mild steel, building one over the other on the barrel, instead of the thick hoop of hard steel, as called for in the Ordnance Specifications. The strength and reliability of the gun will increase *for the same weight proportionally as the thickness of the hoops decreases* to a practical limit. All that is necessary is to find out by experiment what is the proper thickness of hoops consistent with weight, strength and cost. This thickness may be found to vary with the size and use of the gun. The gun to be used in fortifications need not be so light as that for use on ship-board. Suppose, for illustration, that instead of using thick hoops of hard steel, twelve hoops made of mild steel be used, placing one over the other. By putting the proper amount of work on these, the tensile strength can be raised very high without impairing the quality; moreover, if by any chance one or two of these hoops should break or fail, the remaining ones will be ample to sustain the strain, as they would always be used with a large factor of safety. A gun, if properly constructed and proportioned, made in this manner of mild steel, could not fail, even with any reasonable amount of bad treatment. This is a practical application of the old adages: "In union there is strength"; and "Not to put all your eggs in one basket."

The steel that I advise to be used for making guns is the ordinary mild steel of commerce, made by a great many establishments in the United States in large quantities, and which can be had at any time in any desired quantity. It is now selling at about sixty dollars per ton.

The hard steel called for in the Specifications is a special product, not used to any extent in commerce, being too unreliable and expensive for any commercial use. It must be manufactured to order, and, owing to this and to the severe specifications, the cost will be great.

By the use of many and thin hoops, or cylinders, of mild steel, properly built up and proportioned, a gun can be made that will be at all times safe, reliable, and unfailing. If hard steel, or steel of high tensile strength, in thick hoops, is used, the gun will be more costly, and of greater theoretical strength, but practically much weaker, and will fail when least expected, and without any apparent cause or reason. If it is necessary to have thick hoops, as called for in the Ordnance Specifications, make them of mild steel, giving the necessary strength by additional material; this may make a heavier gun, but it will always be safe and reliable. Hard steel should not be used until much more is definitely known of the *supposed* improvement of the oil temper on large pieces or masses of metal.

## DISCUSSION.

The chairman addressed the meeting and stated that a large number of replies had been received from steel makers and experts to whom proofs of Mr. Dorsey's paper had been sent; that he was glad to see present a number of prominent gentlemen who had responded to the invitation, and that the Board of Control had suggested an arrangement for the meeting which he would follow in calling upon speakers to take the floor. He then requested Lieut. C. R. Miles, U. S. N., to read communications received by the Institute, and the following were presented to the meeting, viz.:

### Dr. RICHARD J. GATLING, *The Gatling Gun Company, Hartford, Conn.*

I shall not attempt to add anything to what has been so well and appropriately said by Mr. Dorsey in his lecture. I am wholly in accord with his views.

I believe that a mild or low grade of soft steel will be a cheaper and better material for making heavy guns (especially guns for fortifications) than hard steel. I have found in my experience that hard steel, even when it is well and carefully tempered, is far more

treacherous and easily broken or fractured when subjected to violent shocks than soft or mild steel. For instance, firing-pins and gun-lock hammers, when made from well-tempered hard steel, are less durable and more liable to break than when made of mild steel.

It is difficult to temper large masses of hard steel so as to have all parts of an even temper or homogeneous. Although such steel has great tensile strength, nevertheless it is quite brittle, and when subjected to sudden and violent strains is more liable to break or crack than soft or mild steel.

When large guns are fired with heavy charges, there is great strain on the parts, causing more or less vibration of the whole structure of the gun. In other words, the repeated firing of a gun will produce what is known as the fatigue of metal, and when that occurs and the metal becomes more or less crystallized (and which in my judgment is more liable to occur, and to a greater degree, in guns made of hard than in those made of mild steel), the lifetime of the gun may be said to be at an end. At all events, when a gun gets in such a condition, it becomes liable to burst, and is dangerous to the men using it.

Professor R. H. THURSTON (*formerly of the U. S. N. Engineer Corps*), *Director of Sibley College, Cornell University.*

I have read the paper of Mr. Dorsey with great interest, and am very strongly in sympathy with his ideas, as there presented. I have had a tolerably long and extensive experience with modern steels, as well as with all the other common materials of engineering construction, and am fully convinced that, in the absence of more definite and much more satisfactory knowledge of the precise effect of the several elements present in the steels, both as affecting their behavior under slowly applied and rapidly imposed stresses, and their endurance for long periods of time, loaded or unloaded—for the effect of time on the unloaded metal is sometimes serious—the only safe course is to use such steel as we know to be safe under all known conditions and indefinitely as to time. We learned, after some years of persistent attempt to make use of the stronger steels in steel rails and in steam-boiler construction, that it was unsafe to use them; we are now only beginning to see that they are just as treacherous in other constructions, and that ordnance is no exception to the thus far apparently universal rule. We have come down to the use of a metal which is not steel at all, in the proper sense, for all other constructions exposed to heavy stresses—a metal to which we should apply the

name given by the International Commission of Engineers, "ingot iron." It is simply a homogeneous iron, an iron free from slag and fibre, and thus possessed of all the good qualities of the best puddled irons, without any of their defects, except, in some cases, such as may have been brought in by the introduction of an excess of manganese, or the use of ores containing phosphorus in noticeable quantities. It has been the universal experience of engineers using steel for civil constructions that the further we recede from the character, as to composition and strength, of wrought iron in such cases, the less safe and satisfactory is the result. In seeking tenacity we surrender ductility and resilience.

There are, undoubtedly, some evidences of the practicability of making successful application of harder steels. Mr. Wm. Metcalf has found that the best steel for steam-hammer piston rods—where the blows are severe and the jar and vibration perhaps greater than in any other case familiar to the civilian-engineer—is steel made in the crucible and containing about 0.8 per cent. carbon. It is possible that this metal can be used in ordnance; but it would be wise to settle that question on the small scale first, by using it in steel howitzers, and to defer the making of a large gun until the smaller sizes had been proved safe. The process of oil-tempering is one which has given remarkable results on a small mass of even high tool-steel; but it still remains to be shown that great masses are to be safely treated for ordnance purposes in this way. I think it very possible that it may prove that they may; but it is certain that the doubt remains, as yet, too serious to permit the expenditure of large sums on the assumption that we may absolutely rely upon such methods of securing strength, elasticity, homogeneousness, and permanence of good quality. I should certainly not urge the suspension of all efforts in that direction; but I should, by all means, advise caution, in construction, in going ahead of our experimental knowledge.

The requisites of good ordnance steel are, in my judgment: First, permanence of such good qualities as the metal may at the beginning possess; then I would look for a certain elasticity within small ranges of distortion; ductility for larger changes of form; perfect uniformity; and, last of all, a certain maximum strength consistent with the possession of these still more essential properties. Ingot iron at 60,000 pounds per square inch, with the ductility and elasticity, the homogeneousness and the permanence of good quality which we know it may be made to offer, is vastly to be preferred to stronger

steels deficient in these other essentials. It will make a better gun than the built-up iron guns of Armstrong and other makers, which, as now seems certain, were more serviceable than the best of recent steel ordnance made of high-grade steel. It seems even doubtful whether Krupp's guns are, on the whole, a better class of ordnance than the thoroughly well-constructed wrought-iron gun. The effect of stress and of time on the wrought iron is known to be at least not injurious; it is not so certain that this can be said of any steel gun, of whatever grade above that of the best ingot iron, low in manganese.

I have always had great faith in the methods of securing density, homogeneousness, strength, and elasticity, practised by Whitworth and his followers. It is now something like fifteen years since I made a report, by request of the Admiral, to the Navy Department, after a summer abroad, and a visit to the Whitworth establishment, urging that the Department take immediate steps to secure the necessary means of introducing this process, at least experimentally, into our own country, for the main purpose of obtaining ordnance that might be relied upon to do good work with equal certainty on all occasions and at all ages of gun, and the subject has been often revived since then. The supineness of the British, as well as other governments, including our own, in this matter, has always appeared to me marvellous. The work of Whitworth, for nearly a generation, has proved the value of his methods so absolutely; the introduction of his steels into constructions in civil and mechanical engineering has gone on so steadily and satisfactorily, and the grand facts asserted by him have been so many times, so constantly, proven, that it seems hardly less than a miracle of unbelief that could have prevented our own and other governments availing themselves of it for their own purposes, to which the process so perfectly and specially adapts itself. It is barely possible that other means may be found of securing equally well the qualities which to-day make the Whitworth process and its product peculiar in their excellence and effectiveness; but, while we are waiting for them, the world moves, and we are relatively going astern. I think that there are several inventors in this country who are working in that line of improvement, and it would seem easy for our Government to secure all the aid that it may desire in developing its own system of manufacture of heavy ordnance on well-understood and thoroughly proven lines.

THOMAS C. CLARKE, C. E., *Union Bridge Company, New York.*

The undersigned concurs with Mr. Dorsey in his views as to the superior uniformity of a low-carbon or "mild" steel.

A sufficient number of experiments have been made by bridge constructors to establish this as a fact beyond the shadow of a doubt.

By mild steel, we mean steel having an ultimate tensile strength in large sections of not over 65,000 pounds per square inch, an elastic limit of 35,000 to 40,000 pounds, and a stretch in full-sized sections of at least $\frac{20}{100}$ in 10 feet, and reduction of area at point of fracture of about $\frac{50}{100}$.

The process of upsetting and forging eyes on the heads of bars causes a *flow* of the particles of steel to an unusual extent, and sometimes involves hammering at a blue heat. Yet it is a very uncommon thing for a steel eye bar made of this material to break in the eye; while steel eye bars made of 90,000 pounds steel would behave most unaccountably, one breaking in the eye with 40,000 pounds to the square inch area of bar, and another running up to over 90,000 pounds.

It seems reasonable to suppose that high steel forged into hoops for guns would behave in an uncertain manner, while low steel would give uniform results.

The undersigned, never having had any experience in the manufacture of such hoops, can only reason from analogy.

THOMAS C. CLARKE,

*Member Am. Soc. Civ. Eng.; Institution Civ. Eng., London; Am. Phil. Soc.*

*December* 17, 1886.

Professor THOMAS EGLESTON, *School of Mines, Columbia College, New York.*

I have yours of December 9th, with the enclosed document inviting me to be present January 5th, to take part in the discussion of the question of steel for heavy guns. I regret that I am unable to be present at Annapolis to take part in the discussion, and all the more so as, since before the Government commenced agitating this question, I had been very much interested in it. Independently of the researches which I have made in this matter, I have been several times to Europe and have studied this question in almost every large manufactory of ordnance there.

For the last eight years I have been earnestly advocating a test commission as the only way of settling this question, and many others of a similar and equally important character.

As I have said in some of my papers on this subject, there is every reason why steel guns should be manufactured; but there is much to be done before we can successfully make them in this country. General Rodman made cast-iron guns of a superior quality and educated the country up to his ideas. The limit between steel and cast iron is not wide, but the difficulty of managing it is no greater now than of learning how to make cast-iron guns of large size was then. We shall have to do for steel what General Rodman did for cast iron. One of the greatest difficulties in manufacturing steel in large masses is that people insist upon hammering it, and, so far as large masses of steel are concerned, they never should be touched with a hammer in any stage of their manufacture. Hammering generally makes steel brittle, except in very small sizes, independently of the whole question of blue temper. I have seen masses of twenty-five tons of steel cast and pressed so that tests throughout the steel showed absolute uniformity and very great toughness, with no tendency towards cracking; and, on the other hand, I have in my possession at the present time a photograph of a very large hammered crank pin, made of the best of steel, under the most favorable circumstances, which is riddled with cracks in every direction, some of which were ten inches long and half of an inch wide. The greatest difficulties in the matter are the questions of occluded gases, liquation of the elements, which takes place, as is not generally understood, not only from the top towards the bottom, but from the sides towards the centre of very large castings. This is, however, a purely mechanical difficulty, which can be entirely overcome.

I am glad your Institute has raised the question and brought it to the attention of naval men, for the only thing that is wanting in this country for the manufacture of such material is the certain patronage of the Government. There is no place in the world where there is finer material than there is in this country. There are no better steelmakers in the world than some of those who make high-grade steel in the United States. The ability and material are all here, but the demand for large masses of steel can only come from the Government of the United States; and, therefore, as it is the only customer possible, it should guarantee for a period of years orders to an amount sufficient to justify capitalists in erecting the necessary

plant. When these conditions are fulfilled there will be no real difficulty in solving the problem of heavy steel ordnance better and more economically than has been done by any of the governments of Europe. I have seen too many of these heavy guns made, and too much of the various metallurgical establishments of the Government of the United States, to ever believe that it can manufacture such ordnance in its own shops. It will have to be done by private enterprise, supported by Government patronage, if at all. I have, unfortunately, been on board several cruisers in Europe which could, without fear, enter any port of the United States, including New York, and levy any tribute they chose, and get safely away for the time being. This is mortifying, in view of the fact that we have, as is acknowledged by all the governments of the world, greater resources and greater mechanical engineering ability than can be found anywhere else. After the close of the war I was fortunate enough to be a member of the commission which examined the armaments of the forts of the United States, and saw, under injunction of secrecy, thirteen inches of iron pierced for the first time. I went immediately after that to Europe in time to hear of the experiments at Shoeburyness, where nine inches of iron were pierced, which was considered an immense feat. There is no reason why the United States should not be as far ahead of the rest of the world now as then; but, unfortunately, we have rested satisfied with what we have done, and have lagged behind.

As you see, the question of the use of steel for guns is not a new one with me. I have been perfectly satisfied for a number of years that steel guns of any calibre could be manufactured in the United States, if the requisite conditions were to be fulfilled. But there is one thing that must *not* be done, which is, that steel in large masses must *not* be hammered; and as it is impossible to entirely prevent the occlusion of large quantities of gas and the consequent blow-holes, and the concentration of impurities by liquation from the top towards the bottom and from the sides towards the centre, powerful presses are the only way in which such large masses of steel should be treated.

Yours truly, THOS. EGLESTON.

Mr. WM. HENRY BROWN, *Manufacturer of Seamless Steel Tubes, Jersey City, N. J.*

*Gentlemen*:—In addressing you upon the subject of steel for heavy guns, I must be permitted to so largely differ with the construction

of guns as now existing generally, that I feel, unless I am present with deeds, my sayings will not command the attention they deserve. Experience has been my teacher, and founder of all I say. I have been a worker of mild steel, from the seamless knife-handle up to the cylinder or tube twelve inches in diameter, and in thickness from half an inch down to the paper I am writing on. As a manufacturer of all metals during my life, and having the experience of my ancestors before me, I am prepared to demonstrate that you can do anything with mild steel that you can do with copper, and on account of its greater tensile strength it will bear a greater reduction in cold-working. Mild steel is in its infancy for all structural work. It is the coming metal of the age for all uses, and the only cheap metal that will bear any amount of abuse with impunity. If this mild steel is carried into structural use without changing its homogeneity in the process, we have met a large demand. This is what we claim to have accomplished, adding thereto, by compression and drawing, an increased tensile strength that permeates alike the entire thickness *uniformly*, without shock or chill, easily reaching 100,000 pounds, or over, tensile strength to the square inch. The oil-temper is only a chill on the surface, does not give uniformity throughout, and in hard steel it is capricious. Shock, expansion and contraction destroy the structure in a short time, and in its natural state is too unreliable for any structural work. Such has been my experience. In entering upon this discussion for heavy guns, I take the position that you cannot *cast* hard steel into form on account of *cavity*, and that hoops and bands are not reliable, and have no longitudinal support.

But we can take a disk of mild steel, and by forming it up hot, and by compressing and drawing it cold, finish it so as to gain a tensile strength that will reach any demand required for safety and reliability. Let me take up the construction of a 6-inch gun (although it is equally adapted to all guns), and consider the tube bore and rifling as satisfactorily constructed. I take a circular plate of steel boiler-plate, say one-half inch, more or less, in thickness, heat it, and dish it up by hydraulic force. This process is repeated, a smaller die and punch being used, until the shell has reached the required diameter and length for finishing. In a like manner similar shells of a larger size are produced for reinforcing to any extent desired. Taking the tube bore of the gun which we desire to cover, and which constitutes the mandrel for compressing and drawing the first shell, I cover the tube with the shell, and, to make it more firm, pass it through a

smaller die, compressing the shell and at the same time giving it a greater tensile strength by elongating it upon the tube bore. In a like manner I add as many of these half-inch reinforce cylinders as may constitute a positive factor of safety. It results in a construction of maximum strength and minimum weight free from cavity; any fault in material is sure to show itself before the shell is finished; it reaches a tensile strength which has no equal; and the result has in no way detracted from the acknowledged high qualities of homogeneous open-hearth boiler plate. There is no waste of material. The shell is positive in itself, in all its appointments, and carries the motto—"In union there is strength." By this cold process the shell can be hardened almost indefinitely without destroying its tensile strength.

It is said mild steel cannot be tempered. I have been and am making from this same steel die rings one and a quarter inches by twelve inches diameter, turned or cut in a lathe from the sheet, and so tempering them that a file will not touch them, and we use them for cold-drawing this same steel. Of course the character is completely changed; and this process I propose to apply to armor plate later on. The tubes for all guns, certainly the smaller ones, can be made and tempered by this process after rifling. By this method you overcome jackets and chase hoops, and *gain longitudinal strength*, which is lacking in all other methods. You firmly hold and make secure against inertia the tube bore of the gun. You get maximum strength and minimum weight. You are in open market, with plenty of producers to compete with for material, and a consumer of the cheapest of all reliable metals—mild steel. Experience tells me there is no metal like it. Shrapnel shells, the coming projectile, with a plane of weakness in front of the charge, are readily and uniformly alike produced by this process. In conclusion, I only confirm the views of others when I state from practical experience that a gun built up with cylinders, as described, from mild steel, must supersede all other methods, on account of *durability*, *cost*, *safety*, and *rapidity of production*.

The subject is one covering too large a field to be gone over satisfactorily in an article of this character. If, however, the views herein expressed are deemed to be worthy of further investigation, I should be pleased to meet any expert and with exhibits show what can be done with mild steel.

Yours truly,

WM. HENRY BROWN,
47 Montgomery St.,
*Jersey City, N. J.*

Calculation for a six-inch by six-foot steel gun, each plate being one inch thick :

| | Weight lbs. | Diam. of Plate (inches). | Combined Resistance per sq. in. lbs. |
|---|---|---|---|
| First shell..... | 451 | 45 | 28,000 |
| Second shell..... ..... | 400 | 43 | 50,000 |
| Third shell..... | 300 | 38 | 68,000 |
| Fourth shell..... | 270 | 33 | 82,000 |

The total weight would then be only 1421 pounds, while the resistance would range from 28,000 pounds per square inch at the muzzle to 82,000 pounds at the butt. The figures denoting the power of resistance are obtained by deducting from the tensile strength of steel 100,000 pounds per square inch, the multiplied area of the inner surface. W. H. B.

Mr. S. T. WELLMAN, *Superintendent of the Otis Iron and Steel Company, Cleveland, Ohio.*

It seems to me the argument that Mr. Dorsey holds out is, that because mild steel has been proved to be the best material for structural purposes and for steam boilers, therefore it is the best for heavy guns. It seems to me that the kind of strain put upon steel boiler-plates and structural material is of an entirely different kind from that to which gun steel is subjected, the former having to withstand nothing but steady loads, while the latter is continually subjected to shocks, and those of the most severe kind. In our line of business we have had no experience with steel for heavy guns. The nearest thing to the kind of shock to which gun steel is subjected is that which steam-hammer piston rods have to stand. It has been repeatedly proved, by many experiments with both kinds of steel, that hard steel, and that above .50 per cent. in carbon, stand many times longer than soft steel, and that the softer the steel the shorter the life of the rod.

The same thing holds true with everything in steel that has to withstand severe vibratory shocks and strains.

It would seem that the Ordnance Departments of our Army and Navy were doing the correct thing in copying the best practice on the other side, until from our own experience we can make an improvement on it, which I have no doubt will come in a very short time. I don't suppose it is a fact (as Mr. Dorsey's paper would seem to imply), in fact I know it is not, that the ordnance officers are going

ahead in the manufacture of heavy steel guns without thoroughly testing in every possible way the material while under process of manufacture, and the guns themselves at the proving ground when finished.

One thing has not to my knowledge been proved, as yet, and that is that the high ductility that is asked for in hard gun steel is at all necessary. If this should prove not to be the case, then I see no reason why as good, if not a better gun, cannot be made by some modification of the Rodman process applied to a steel cast gun. There is certainly no trouble in reaching a tensile strength of 100,000 pounds per square inch. The experiment of making and trying such a gun would be quite inexpensive, and would seem to be well worth trial by the Ordnance Departments.

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Lieutenant R. R. INGERSOLL, *Head of Department of Ordnance and Gunnery, U. S. N. A.—Mr. Chairman and Gentlemen:*—The paper on "Steel for Heavy Guns" we have heard read, if I correctly understand its meaning, makes very radical assertions. We learn from it that gunmakers, both in this country and abroad, are now pursuing, and have for years been pursuing, a mistaken course in regard to the grade of steel which they consider necessary to use in gun construction.

We are told that the steel demanded by experts in ordnance is an unsafe, unreliable, and treacherous metal by nature, and that to this capricious character of the steel all of the failures of steel guns are directly chargeable. I submit that, if true, this is a lamentable condition of things, and is of vital importance to every one who is interested in the work of the rearmament of our Navy and coast defenses. If true, it means simply this—that all the study, experience and experiments of the past years, by men whose education and life-work have fitted them especially for that duty, have tended to confirm a mistake, and that the whole work of investigation should be commenced anew. Are we prepared to accept such a conclusion? We have heard from time to time criticisms on this or that feature of gun construction—generally by some advocate of a new gun—or of cheap material such as cast iron, or of casting guns on the Rodman principle, etc., etc., but this paper seems to be the first public criticism of the general quality of the steel which ordnance experts deem necessary for their purpose. It must be said, also, that a numerous

class would be glad to see the standard of specifications for gun steel reduced for other than the very worthy motive of the lecturer, which seems to be a conviction that the steel now required is, while nominally a stronger and better metal, in reality a weaker metal for guns than a grade of steel which he proposes. He tells us that if the mild steel, which he defines, is used, we shall always have safe, reliable and strong guns—stronger in reality, though built of steel of less tensile strength than is now the practice wherever steel guns are built. It is to be hoped that a discussion of the subject will be given us from the standpoint of the expert in the manufacture and use of steel in large masses, such as are necessary for guns. Certainly some of our manufacturers ought to be able to tell us whether or not the steel which they have furnished of a tensile strength of 90,000 pounds and upwards is the unsafe and treacherous metal, as stated by the lecturer, and whether steel of 60,000 pounds tensile strength in large masses is always the safe, reliable metal it is declared to be.

It occurs to me that perhaps the difference of opinion, between the lecturer on the one hand, and ordnance officers on the other, as to what is the proper metal to use for guns, may be due to the different standpoints from which these two classes of professional men view the subject. We must defer to the high authority of the opinions of civil and mechanical engineers on the use of a proper metal for machines, bridges, boilers and other structures which come within the limits of their professions and experience; and while a gun may be perhaps called a machine to do certain work, yet it appears from this paper that the able lecturer has not exhausted the subject of the construction and working of this particular machine, a steel gun, the strains upon which differ in character from that of every other mechanical structure, and which in gun construction necessitate the taking into account of very many other matters besides the one fact that the steel shall have a fixed *tensile strength*. This leads to the belief that it perhaps may be shown that the lecturer is mistaken in his view of the matter.

Before attempting to show wherein he is mistaken, as viewed from the standpoint of ordnance officers, it may be proper to say that it seems a very broad and radical statement to make, that because a failure has happened here and there, out of a very large number of trials, that on that account the whole should be condemned; and, in this connection, I have been very much struck with the remarks of Mr. William Kent, mechanical engineer, of New York, on "The

Recent Failure of Steel Boiler Plates in England," published in the *Transactions of the American Institute of Mining Engineers*, Vol. XIV. After reviewing the various theories advanced to account for the singular failure in question, Mr. Kent says: "To charge the failure of this steel to the treacherous nature of steel in general, and to say that nothing the steelmakers can do will prevent such failures, is both illogical and unscientific."

"If the failures of steel boiler plates were a matter of every-day occurrence, we might justly call steel a treacherous metal; but when the plates that fail are not one in ten thousand of the plates that are made, it would be more logical to say that steel is the most trustworthy of all metals; and, when a fracture does occur, it would be more scientific to say that there must be some unusual cause for it, and to attempt to discover that cause, than simply to charge it to the 'total depravity' of steel in general, and say it cannot be prevented."

I claim that this sensible opinion will apply with equal force to the criticisms of the particular grade of steel now used for heavy guns, when those criticisms are apparently based on no other foundation than the fact that here and there a steel gun has failed. Really, the failures within recent years have been very few indeed. We know of two failures in England—both guns failed at the chase, where the gun was not strengthened by hoops. Rumors of the failure of some of the De Bange guns have been current, and it was also reported that some of Krupp's guns had failed at Constantinople, but this has been most emphatically denied by Krupp. No steel gun of American manufacture, and of the present construction and design, has failed. We do not hear that any of the foreign governments interested have been so badly scared by the exceptional failures as to commence anew the armament of their ships and batteries with guns built of steel of the character that the lecturer recommends, and in general, so far as the evidence available goes to show anything, it is, in the proportion of more than a thousand to one, in favor of continuing in this country the work of gun construction, in just the line in which it has been so happily begun. The very unusual event of a gun failing, from whatever cause, is quickly seized upon by news-gatherers, and made too often to form the basis of a sensational newspaper article attacking the policy of those responsible for the work, while the same newspapers are not always so ready to publish a reason for such a failure, if one is forthcoming, or to contradict the report of failure if such report is found to be untrue. So, we hear all about the few and

exceptional failures, and but little concerning the thousand successful results.

Now let us consider a few points a little more in detail. The lecturer defines gun steel by its quality of *tensile strength* alone, but he says nothing about the other qualities, which are of much greater importance to gunmakers; and it cannot be accepted as a fact, that the other qualities bear a constant ratio to the *tensile strength*, which the lecturer seems to consider of first importance. In designing bridges, machines and boilers, the *tensile strength*, combined with an assumed factor of safety, limits the load the structure is calculated to stand, and this one quality is always kept in view. With gunmakers, however, the tensile strength is not considered at all in the design of a gun, but the elastic strength and the ductility—or elasticity, if you please—of the metal within its elastic limit. Therefore the *elastic strength*, or the ability of a gun to resist permanent deformation, and *not* its *tensile strength*, or its ability to resist fracture, is the quantity which limits the safe load with any assumed factor of safety. The ratio of the *elastic strength* of a metal to the *tensile strength* may vary from .4 for steel of 55,000 pounds tensile strength to .6 with steel of 130,000 to 150,000 pounds tensile strength. The ductility, or percentage of elongation after fracture, may vary from twenty-seven per cent. with the former, to sixteen to eighteen per cent. with the latter. Again, these ratios vary with steel of the *same* tensile strength, depending upon the manner of treatment and amount of work done on the metal after casting. It is as plain as possible, that simply giving the *tensile strength* of a metal really tells very little about its fitness for gun construction.

The reason we use the elastic strength of a metal in designing guns is obvious to those who have to use the guns. The strains to which a gun is subjected are not simple rending strains, but are vibratory in character. We work within the elastic limit always, and, moreover, seek a metal which has a large percentage of *elastic elongation*, or elongation within the elastic limit, which characteristic aids the metal to resist the vibratory strains to which it is subjected. If the bore of a gun is permanently deformed an appreciable amount by firing, the results would be a loss of velocity and perhaps insufficient rotation of the projectile, causing a loss in range and inaccuracy of flight. Again, the parts of a gun are assembled with a definite shrinkage, and so put together that when a certain powder pressure acts, all the parts will pull, at their interior surfaces, at the elastic limit of each. This

powder pressure, or the load, that will cause the parts to all act together, is called the *elastic strength* of the gun.

Let us investigate the elastic strength of a gun built of the steel such as is proposed by the lecturer. We require a gun to do certain work; what that work is, I claim, is best known to those who have to use the guns; and it may as well be said here, as ever, that the Navy is not prepared to accept, without protest, guns which are not the equal in all respects, calibre for calibre, in capacity for work, with those that are likely to be pitted against us.

The people who use the guns are competent judges, too, of what factor of safety should be allowed in assigning the safe powder charge to use. If the steel proposed by the lecturer will not build a sufficiently strong gun to do the same work as those now being built, and allow an equal factor of safety, it is idle to discuss the advisability of its use for gun construction. Take a six-inch gun as an example. We require it to throw a 100-pound projectile with an initial velocity of 2000 f. s. The travel of the projectile is 24.4 calibres, which, with the length required for powder chamber and breech plug, makes the gun as long as it can well be for naval purposes. We want this definite amount of power to give range, accuracy of fire, and a certain penetration of armor at a given range; less than this amount will on no account suffice; to accept less is to confess our inferiority, gun for gun, with every naval power on the globe. This definite power is now obtained with the gun in question with fifty pounds of Dupont's cocoa powder, and the maximum pressure does not exceed fifteen tons per square inch. The *elastic strength* of the six-inch gun, as now built, is twenty-three tons at points where the maximum powder pressure acts; so the factor of safety is $\frac{23}{15}$, or about $1\frac{1}{2}$, a factor none too high. Now, with steel of 60,000 pounds tensile strength, the elastic strength being assumed at 30,000 pounds, which is in favor of the steel, a six-inch gun built on the present dimensions gives, by Clavarino's formulas, an elastic strength of 14.7 tons, a quantity a little less than the maximum pressure, which, you remember, is 15 tons—no factor of safety in this case, certainly. We should have the bore permanently deformed with every round. Evidently, the same weight of steel, in the same form as now used, will never do. But the lecturer says, "Use a great number of thin hoops, if we must have light guns, instead of the thick hoops." Carrying out his idea to an extreme limit, we get a gun whose elastic strength approaches that of a gun in which the tension is uniform throughout the thickness. If such a

gun could be built, the *elastic strength* would be 1.4 times the elastic strength of the metal, or 1.4 times 30,000 pounds, or about 18.7 tons. So we see that any possible construction will give a strength between 14.7 tons and 18.7 tons, and I submit that the factor of safety with any such gun would be entirely too small, especially in view of the contingency of a premature explosion of a shell in the bore—an event not unlikely, and which would leave its mark in no slight manner on a gun of such low *elastic strength*. Gunmakers are already committed to the plan of very thin hoops for the outer layers, as is exemplified in the case of wire-wound and ribbon-wound guns; but the steel in the form of wire or ribbon has a very high elastic strength. There are certain mechanical difficulties, such as tight joints, soldering, etc., in the way of its use at present, but the moment these difficulties are overcome—and they will be overcome in time—the pressure on the gun will be increased fifty per cent. above what it is now, and the *low-tensile-strength* steel of the lecturer will be more than ever inadmissible for our purpose.

But he says, "If thick hoops must be used, make them thicker of the low steel." This proposition will not do for the Navy, at least; it means increased weight, gun for gun, or a less number of guns to a ship of given tonnage, than is now able to be carried. It means a decrease of our fighting power for a given expenditure of money in ships, coal, equipments, and pay of officers and men. The tendency should, in the opinion of naval men, be rather in the other direction, if possible—lighter guns of the same or greater power, and more of them. Aside from this, it can be shown, without a shadow of doubt, that beyond a certain limit the strength of a gun is not increased materially by adding to the thickness of its walls, since the power to resist internal pressure does not increase proportionally to the thickness.

The lecturer says nothing whatever in regard to the effect of *annealing* on large masses of steel. I presume he will not deny that its effect is most beneficial in producing that uniformity of molecular construction which is desired, and in getting rid of the internal tensions that may exist in the mass, before the steel is subjected to that process, and to which is attributed the unreliability of steel of high grade. He questions the effect of oil-temper on steel in large masses such as are used for guns, and, on this point, such experiments as have been made go to show that its effect is undoubtedly felt throughout the mass. I merely wish to quote one experiment. You will find a

record of it in the report of Captain Rogers Birnie, Ordnance Corps, United States Army, to the Chief of Ordnance, published in a "Note on the Construction of Ordnance," No. 32. In that report a tabulated statement is given of the tests of specimens taken from two cylinders made by Whitworth, of forged, oil-tempered and annealed steel of the quality demanded for the construction of an 8-inch steel gun, and of cross-sections corresponding to those of the tube and jacket of such a gun. The cylinders were twenty-four inches long, and specimen rings were cut out near the middle of the length of the forgings; from these rings test pieces were taken—not near the circumference alone, but some near the centre of the thickness, and others radial. The specimens were tested at the Watertown Arsenal, and an inspection of the tabulated report fails to show any material difference in the metal throughout the thickness. The effect of the oil-temper or process of working this steel after casting was, in this case at least, more than "skin-deep."

In the absence of any practical experience in this country at the commencement of steel-gun construction, who would be most able to give opinions as to the proper steel to use and the best form in which to use it, foreign gunmakers, who have had years of experience, and who have invested immense sums in that industry, or professional men in this country, however able, who have had no experience whatever, who have not a dollar at stake, and who do not risk professional reputation, even if their ideas should not prove successful?

It would seem that the best interests of the Government, and of the public, lie in a high standard of tests, and that with the constant improvement in the quality of steel produced, and with the gain in the knowledge of that metal, the standard will probably grow higher rather than lower.

What we want with gun steel is uniformity; but this should be a development with high rather than with low qualities, and the tendency and march of events indicate that this will be attained by, 1st, a more intimate chemical knowledge of steel; 2d, a less barbarous forging machine than the hammer; 3d, annealing; 4th, oil-tempering.

It seems to me, gentlemen, that we have gotten beyond the experimental stage, with the smaller calibres of naval guns, at least, in this country, and what more could be learned by a new set of experiments with guns built of the steel proposed by the lecturer, is not evident, unless, perhaps, that it would be shown, beyond a doubt, to that gentleman and those who support his views, that a gun so constructed

would not suffice for the work we require. That fact is known already, however, so far as the interests of the Government are concerned, without the expense and delay of experiments.

The guns, as now built, have stood every reasonable test that may be demanded of them, the problem of what kind of steel it is best to use has been solved to the satisfaction of those who will have to use the guns, and all we ask, in the event of war, is to be allowed the privilege of defending our flag with just such guns as are now being made.

Lieutenant-Commander F. M. BARBER.—*Mr. Chairman and Gentlemen:*—The essay before us comes at a most opportune time in the history of modern gun fabrication in the United States, because it probably represents, in a general way, not only the ideas of most manufacturers of steel in the United States, but of citizens generally, except such as are interested in cast iron or unforged cast steel.

From the nature of his treatment of the subject, it is difficult to criticise the article as a whole, because the author does not go sufficiently into details for one to be always sure of what he really means, and it is not fair to assume that he means one thing when he might mean another.

It seems, therefore, better to merely point out in a general way and at some length what appear to be doubtful or debatable points that strike one in reading over the article; such points as in my opinion would tend seriously to vitiate the argument of the essayist.

First and foremost, there is no mention whatever throughout the entire article of the *elastic limit* of the metal, or of the process of *annealing*.

To the ordnance expert, this absolutely ruins the whole argument of the essayist; but, as it is to be hoped that, for the benefit of the service, the article and its criticisms will receive a wider circulation than among our officers, it is necessary to proceed more at length.

The elastic limit, and not the rupturing limit, marks the boundary of the artillerist's working range, because it means to him the power of the metal to endure vibrations and still return to its original form. It contains the only valuable part of the power of elongation of the metal, so far as he is concerned, and the more of this elongation he has within his limit, the better he is pleased. The ductility or stretch outside of his limit he cares little about. The better the steel, the higher the elastic limit, the more of this elongation within it in

proportion to the total elongation, and consequently the wider the artillerist's range.

The rupturing limit only means the capacity of the metal to endure loads, and perhaps undulations, as in a bridge; but most civil engineers, now-a-days, are of the opinion that even when steel is used for ordinary commercial structural purposes, working loads should be determined with reference to the elastic limit.

Roughly speaking, the elastic limit is about half the rupturing strain, and, therefore, with the steel of 60,000 pounds per square inch tensile strength, the elastic limit would be a little more than 30,000 pounds; this is somewhat less than the pressure in the powder chamber of the 6-inch or 8-inch guns, which have been safely through the statutory test at Annapolis, and which would have been permanently deformed and ruined if made of the steel in question.

With the steel advocated by the essayist there is practically no elastic limit to work on, bearing in mind what has been said about the amount of elongation inside the elastic limit in proportion to what is beyond it, and also bearing in mind what pressures we must consider. Krupp states (see *Army and Navy Register* of December 18th) that a pressure of 18.76 to 19.52 tons per square inch *is not excessive* for his 118-ton guns.

This can best be illustrated by an example or comparison of the results obtained on the same sized test specimen, two inches long and one-half inch in diameter, by a Midvale oil-tempered and annealed six-inch gun hoop and a Chester Rolling Mills low steel plate as near like what the essayist advocates as possible—a little better, perhaps:

| Steel. | Tensile Strength. | Elastic Limit. | Total Elongation. | Elong. Inside of Elastic Limit. |
|---|---|---|---|---|
| Midvale..... | 105,000 lbs. | 60,000 | 19 per cent. | .2 per cent. |
| Chester..... | 60,000 lbs. | 31,000 | 34 per cent.* | .1 per cent. |

Observe the difference in the elastic ratio, and also in the amount of elongation available to the gunmaker. Of course this elastic ratio in the low steel can be raised by "fooling" with the phosphorus and making it higher, but that will make a good test specimen and won't make anything else; the plate will not work or reheat many times.

The elastic limit of the steel of the essayist cannot be increased legitimately, except possibly to a slight degree, by working it, because the metal contains very little carbon and will not temper. The elastic

*This would be about 25 per cent. on an 8-inch test piece.

limit of the gun is increased very materially in building up, but this applies as well to the higher grade of steel as to the lower.

The paragraph commencing "All workers in steel will admit," etc., etc., is excellent, except, perhaps, the remark about the zero of treachery being at 60,000 pounds tensile strength. *All* steel is treacherous to those who do not understand it, whether its tensile strength is 40,000, 60,000 or 160,000 pounds.

The statement that mild steel is the most reliable of all cheap metals, and that it can be *badly worked and maltreated with impunity*, has not been borne out in naval experience. There probably never was as good, and certainly never any better, steel put into vessels than in the Atlanta, Boston, etc. This steel was obliged to show 60,000 pounds tensile, and 23 per cent. elongation, as an average on four test pieces, for hull material; and for boilers the four test pieces could show a variation of from 63,000 to 57,000, but the average must be at least 60,000, and the elongation 25 per cent.; these results to be obtained on a test specimen measuring eight inches between reference points. The French Navy requirements are greater than these; the English Navy demands are less.

The reports of the Advisory Board on this material are used as advertisements to-day by all the people that produced the metal; yet, good as it was (much better than Lloyd's Registry demands), it had to be carefully handled and never abused. To bend the end of a deck beam, for example, always required skill and care; it had to be nursed round a corner, so to speak, and if improperly treated, like bending it at a black heat, or overheating, it would break. Tube sheets also sometimes gave trouble;* but the total number of failures was very small, because care *was* exercised, and the men were skilled. This material, *intelligently* treated, would do anything that ship and boiler construction required of it.

The essayist persists in referring to gun steel as HARD steel, and he sets up an arbitrary definition of hard steel in which he places the tensile strength at the rather low figure of 90,000, and specifies neither the elongation, nor elastic limit, nor contraction of area. He appears to think, also, that the tube, jacket and hoops are all made of steel of the same physical characteristics. The *untempered* steel that

* In the new circular of tests for steel for cruisers, issued by the Navy Department December 16, 1886, all flanging plates are required to be between 50,000 and 55,000 pounds in tensile strength, with not less than 29 per cent. elongation in 8 inches.

would make the army ordnance hoop that he refers to would probably record forty tons tensile, upward of twenty tons elastic limit, and twenty per cent. elongation. It is simply splendid steel which will take the skilful treatment that will make it still better.

The tube and jacket of that gun would probably demand less tensile strength, lower elastic limit, and greater elongation.

The remarks on oil-temper are not warranted by a thorough knowledge of what good practice is daily producing. If the failure of guns to which the essayist refers proves anything, it proves that the metal was not annealed. Indeed, in the most notable of recent failures, that of the Collingwood gun, the specially appointed commission, in their report of August, 1886, particularly state that one of the causes was "the absence of annealing after forging, and oil-hardening, which treatment would have mitigated any internal strains set up by these processes"; and they say never a word against oil-temper. They concluded by recommending an oil-tempered and annealed material more difficult of realization than our army ordnance hoop, and it would be difficult for the essayist to produce a more competent set of judges anywhere than this ordnance committee and its specially associated members.

Midvale and Cambria in the United States, Creuzot in France, Whitworth in England, and Krupp in Germany, would all differ from the essayist in the idea that the failures of modern guns are largely due to defective oil-temper; they would smile, too, at the idea that Lloyd's had more practical knowledge of steel than they, especially when one compares gun steel with boiler steel, and considers the fact that the experience of these firms extends more or less to both kinds of steel, while Lloyd's is confined to boilers and ship material.

Not only are a boiler and a gun subjected to different kinds of pressure, but the 100 to 200 pounds of the one bears no comparison with the fifteen tons of the other, making all due allowance for the stronger and more compact shape of the gun. It is not surprising, then, that the specifications for a gun should be double what they are for a boiler.

The essayist does not mention the dimensions of the test piece on which his metal is to show 55,000 to 60,000 pounds, and on which its elongation is to be measured. Nothing in steel work leads to more erroneous conclusions as regards the quality of the metal one is dealing with. The 60,000 pounds tensile demanded by the U. S. Navy Department for ship plate, on its standard test

piece, required (as shown by actual experiment at Park Bros.' in Pittsburgh) over 70,000 on the commercial test piece, which was thinner and had less length of uniform section exposed to the strain. Again, American, English and French ordnance test pieces are round, and vary from .5 to .56 square inch in cross-section. In these pieces differences of length (within reasonable limits) have very little effect on the tensile strength; but the elongation is less in percent. as the test piece is longer.

By the reasoning of the essayist from Lloyd's, if the proportion were extended as he extends it, the above-mentioned army ordnance hoop would have a tensile strength of only 50,000, and an elastic limit of a little over 25,000 pounds, or say ten tons, and the walls of a 16-inch gun would give a *minus* tensile strength of over 20,000 pounds on the outer layer. Of what value is such reasoning as that, as applied to guns? Lloyd's Registry is not the best standard in the world even for ships. Their latest rules for ship plate require a tensile strength of twenty-seven to thirty tons, and an elongation of only sixteen per cent. on a length of eight inches; the same test piece that the essayist refers to. That is hard steel in more senses than one, and we would not put it into anything. It is possible to suppose that in England the pressure of commercial enterprise has succeeded in lowering the standard, instead of the general interest of the community and the safety of "those who go down to the sea in ships" having due weight with the Government in keeping the standard up.

To the statement of the Duke of Cambridge regarding the failure of the Krupp guns around Paris, the essayist might have added that, during the campaign of the Loire, twenty-four guns of Prince Frederick Charles were also disabled by their own fire; but this is no proof that the guns burst, as the essay insinuates. Similar statements were made last year regarding the De Bange guns.

As a matter of fact, the number of modern steel guns that have burst in proportion to the number that have not burst is exceedingly small; without doubt it is a very much more favorable showing than steam boilers could make.

The failure of guns "from the effect of their own fire" usually means some defect in the gun construction which has *temporarily* disabled them. It may have put them *hors de combat* forever, but they did not necessarily burst. A failure or sticking of the gas check, or a derangement of the breech mechanism, or damage to it

from prematurely firing the gun, are the most probable; more serious defects than these are slipping of the tube, erosion of the chamber, etc., etc. To all of these, except, perhaps, the very last, the essayist's metal would be still more liable than gun steel, on account of the facility with which it can be permanently deformed.

There is no *if* about the necessity or desirability of light guns for the Navy, where the total ordnance outfit of a vessel is limited to about six per cent. of her displacement. The lightness of our guns should only be limited by our power to control the recoil without tearing everything to pieces about the carriage or ship's side.

There is a mechanical difficulty about turning very thin hoops: they spring to the tool. The thin-hoop system carried to its logical conclusion is the wire-wound gun, and the elastic limit of Dr. Woodbridge's wire is 100,000 pounds.

In conclusion, it may be said that since the metal of the essayist will melt and cast and forge and roll, it possesses an advantage in facility of manufacture over wrought iron for gunmaking; but all these advantages are obtained by the introduction of carbon, and it may almost be said that the good qualities of the metal are in proportion to the carbon; but treachery is introduced at the same time, and different methods must be resorted to according to circumstances to overcome the difficulty.

When the quantity of carbon is very small, say from .10 to .14 per cent., as in the essayist's metal, the treachery can be reduced to small proportions by careful attention to the other chemical constituents, and by careful working of the ingot and shaped articles at the proper temperature and to a sufficient extent; but this is all that can be done, and the metal will still lack the essential qualities of high elastic limit, great elongation within this limit, and high tenacity, which are so necessary in modern gun metal.

These qualities can only be obtained at the present day by the use of the very best ores, more carefully selected than before, and by the introduction of .4 to .6 per cent. of carbon. The treachery here cannot be overcome by simple working; but it can be overcome, and it *is* overcome, by oil-tempering and annealing at proper stages of the fabrication. Any gun steel, however, costs money.

The essayist asserts that his steel can be had all over the country for $60 per ton. There is little doubt of it, so far as thin plate is concerned; but the metal of the Atlanta, Boston and Chicago cost nearer $100 per ton; and neither figure affords any idea of what the essayist's

metal would cost, if he attempted to produce it in the huge masses necessary for the enormous guns of the present day. The idea that it could be had for $60 per ton, as he appears to think, is entirely fallacious. Let him put his figure at $700 to $800 per ton, and he will not be far off from what it will cost him, or any one else, to make steel guns in the United States that will compare with those that foreigners would bring against us.

It appears, then, that the principal objection to the metal proposed by the essayist is that feature for which he deems it most desirable—viz.: that it will not temper. He has introduced the treacherous element without introducing enough of it to make the metal susceptible to the only treatment that enables us to overcome the treachery and bring out those high qualities which are essential to modern guns. At the same time he asserts without proof that this treatment is unreliable and unsatisfactory when applied to large masses, as though this were an additional argument for the use of his metal, which is too poor to be brought up to our standard by any treatment that we know of.

Suppose now we could get this metal in sufficiently large masses and of uniform quality, and were *forced* by the necessities of war to-morrow to use it because we had no other, and fired the gun with powder limited in strength to the capacity of the metal; the weight and size of the gun would make it directly the opposite of what is wanted on board ship, where our great aim is to have as light, handy guns as possible, and as heavy ammunition as possible. We have already reached a point where a hundred rounds of ammunition weigh as much as the gun and carriage, and we hope to do even better.

For land service, the ultimate weight of the body of this gun (of any calibre) would be reached when the process of adding metal to the exterior ceased to give additional strength to the interior—viz.: when one could stretch the bore out of all shape and not know it from the appearance of the outside of the gun. It is not merely a question of adding metal to the outside of the gun till it reaches infinity with *any* system of building up, nor of working the metal indefinitely, because it is possible to work it too much. All the properties that can be put into a gun by building up are thoroughly understood, whatever be the metal, and the experiments that he recommends are not necessary. The ultimate weight added to the gun by increasing its length would depend on the amount of weak, slow-

burning powder necessary to use, and still keep up the velocity of the projectile, now so easily obtained in the light gun of high steel. The essayist's gun could be calculated in either Bureau of Ordnance without difficulty.

Weight, even on shore, has serious disadvantages, which are considered as important by army officers, with reference to casemates and turrets, as they are by us with reference to ships. Were weight and safety not considered, the great cast-iron 12-inch rifle at Sandy Hook would be a wonder in spite of the erosion of its bore, and the fact that its efficiency is only equal to a 10-inch modern steel gun, while its weight is much greater. This cast-iron gun is even *cheaper* than the essayist's.

There is no one in the United States so competent to judge of the kind of material we want for guns as the navy and army officers who have these matters in charge, and the alacrity and skill with which Midvale and Cambria have produced the high quality of material demanded of them, bears ample evidence of the ability of American steel manufacturers to produce the vast quantities of gun metal that we require, if Congress will only appropriate the money that will enable them to risk the erection of the expensive plants that are necessary for the purpose.

The advocacy of a policy or a material that will lower the standard of Government war material as is done by the essayist, is to be deprecated by every officer in the service.

Let us continue in the direction of the thunderbolt and not turn back towards the bow and arrow.

Mr. JOS. MORGAN, JR., *Chief Engineer of the Cambria Iron and Steel Works, Johnstown, Cambria County, Penn.—Mr. Chairman and Gentlemen:*—It is a matter of regret the author has not given more facts and has confined his paper to generalizations and his own opinions. Opinions from an acknowledged expert are valuable, but with opinions against the great mass of scientific knowledge, and the great weight of the views of the most experienced ordnance officers throughout the world, the burden of proof that the scientific world is wrong it seems should rest upon the author. Indiscreet attacks help to unsettle public opinion and discredit the very excellent work done by our own accomplished ordnance officers with very little money from Congress. It is the duty of engineers in civil life who know something of these matters to bear testimony to the care exercised by our own officers in the design of the guns and the selection of material.

The study o structural or bridge steel will not give a correct knowledge of what is suitable for the special purpose of ordnance. The methods of manufacture of bridge steel and ordnance steel are not the same and cannot be so. A bar of bridge steel, say six inches by one inch section, is rolled from an ingot, say from sixteen inches by eighteen inches or fourteen inches by fourteen inches square section extended thirty to fifty times. All crystals, and with them all blow-holes and imperfections, are extended longitudinally thirty to fifty times their original length, and reduced in area from one-thirtieth to one-fiftieth of their original cross-section. The resulting material, if of low carbon, is approximately fibrous, and, made in many cases from ingots originally full of blow-holes, is full of small longitudinal seams of no practical disadvantage in the application to tensile work. Such a material as this was thoroughly tried by the British in their Fraser guns, where the hoops, made of a long wrought-iron bar wound in a coil and welded, were a soft, fibrous material of low elastic limit, such as Mr. Dorsey describes, and these soft coils were shrunk on soft steel tubes. When such material was finally abandoned by the English ordnance officers, under the pressure of the absolute proof that their artillery was inferior to the German and French, they then took up the use of modern ordnance steel and practically acknowledged their previous practice was a mistake. Several of such guns burst, the gun of the Thunderer being one, and another a six-inch at Shoeburyness, with an iron jacket, burst into ten pieces of tube and sixteen pieces of jacket.

How can such treatment as gives us fibre be applied to modern gun material, and is such treatment desirable? The axial extension of gun material and great development of longitudinal fibre will not increase the value of the material to resist tangential or compressive strains while the longitudinal strains in a gun are not comparatively large. If jackets and tubes are manufactured by punching or boring a hole in the ingot and then dilating it, the utmost extension possible in the tangential direction is but two or three times the original length. Those entering this branch of manufacture will find that if there is not absolute solidity in the ingot, no amount of work will give a gun forging that will pass United States Government inspection. A soft steel will not be easier to make solid, and cannot be more cheaply made, if made good. Disseminated blow-holes are fatal to the standard of excellence our officers demand. Mr. Dorsey is in

error in many particulars; for instance, he makes a slight error in saying that mild steel is incapable of taking temper. The ultimate strength and elastic limit of the 60,000 pounds steel may be considerably affected by variations of treatment and consequent variations of crystalline condition, as practical manufacturers of structural steel have found out. We have carefully investigated this fact. Again, he speaks of capriciousness and treacherousness of steel. For this I think we should read ignorance of users. Manufacturers have treated steel as they would wrought iron, in ignorance of the very marked effect upon the characteristics of steel produced by improper treatment.

As an extensively used structural material steel has not been handled for over ten years, either in bridge or guns; but there are manufacturers that by the lessons received in the school of experience know something of its qualities and are learning more all the time. For half a century we have had discussions as to the possibility of crystallization of iron by vibration in use. It is even now a mooted point whether or not a car-axle, for instance, originally of good fibrous material, can become coarse and crystalline in use. If fifty years of experience will not settle all points in the manufacture of iron, can we expect to know steel in ten? We have to-day, and every day, broken car-axles, steel or iron, broken steel rails, one, perhaps, where there used to be one hundred broken iron ones, and breaks and accidents everywhere in machinery in the management of careful and studious engineers. Still in civil life, where the safety of thousands depends upon our judgment, we do not say, "This steel is a treacherous material; let us go back to iron rails and iron tires and axles, and use no more steel." We do say, very properly, "Here are some laws not fully known to us. We cannot afford to drop this cheap and excellent material, but must find out its unknown qualities and use it with greater intelligence." As for the treacherous qualities of steel being zero at 60,000 ultimate, a little experience with plenty of phosphorus will show it capricious at 60,000 pounds ultimate. Nor does the treacherousness of steel necessarily increase with its size, etc. Size has this influence in the manufacture of a material made often in old plants, with machinery too light to put suitable work upon its product, that there is a greater temptation to turn out large bars with too little work. The variation in treatment of large pieces is apt to be greater than in manufacturing small pieces, and hence the variation of result. Nor do the tensile strength and

elastic limit vary, the work being the same if the treatment is the same for the large as for the small pieces. The working temperature, cooling contact of rolls, and possible mechanical differences of treatment, have a great influence upon the character of steel, not afterwards treated, to correct its crystalline condition.

We have heard a great deal about gun failures, and may say that newspaper gossip is generally not sufficiently accurate to supply working data for engineers. I should like some one of the members of this Institute who has seen the official reports, if there are such, to tell us what guns failed. Does not much of this gossip refer to the old Fraser gun, not now held to be a good construction? How many modern steel guns have failed in England, what sizes were they, and in what parts did they fail? And to what tests had the failing pieces been subjected, to ascertain whether they were suitable to put in a gun? If I am not misinformed, there was gross carelessness displayed by the English ordnance officers in this particular of inspection of quality. In this respect they are far behind the French.

An English ordnance board, after the Collingwood explosion, reported that the tube was irregular in quality, and absurdly recommended that test-pieces should be cut out of the tubes submitted, tempered and tested. The ignorance that would take such a test as a measure of the excellence of the tube would do anything.

As to the remarks of the Duke of Cambridge in 1876, it may be he was trying to prove that the English artillery, since then abandoned, was the finest in the world, and, to do so, endeavored to damage the reputation of the Krupp guns, made on another system. Who knows what are the details of these failures he speaks of? There are a thousand minor accidents liable to happen to a siege-gun in the field, to disable it or its carriage; and very possibly a proportion of the thirty-six accidents were such, and were not such accidents involving bursting of tube or jacket. An argument against steel guns supported by no more evidence than such a crude statement made in parliamentary debate is not an engineering argument. Besides, since the date of this statement, ten years ago, referring to guns of probably fifteen years since, much more is known of steel.

As to oil-tempering, the author's remarks may be taken as an expression of opinion from one somewhat uninformed on the subject. Much of the information of this kind is in the hands of a few manufacturers, and is in the nature of special trade skill, not laid open to the general public. Krupp does not make public his methods; nor

do the Creuzot or St. Chamond works in France. All, however, treat their steel in an oil-bath. Few armor-plates of steel would be reliable if untreated. There are manufacturers in this country who know the effects of oil-tempering. They have gained their information in costly experiments, long continued and carefully carried out. It is sufficient to say that no one is likely to reach our present ordnance requirements with untreated steel. When an expert can treat a gun forging to come within three thousand pounds of the desired mark, in a steel which can be made to range in elastic from 40,000 to 80,000, and in ultimate from 90,000 to 130,000, his methods cannot be called unreliable, or the results inconclusive. There are many hundreds of tests which have been made upon tempered steel which will prove the results of tempering very conclusively. That hard steel is a compact substance, is in favor of the rapid cooling effect of an oil-bath and not against it, while the ordnance tests show the cooling effect will penetrate to the centre of the largest gun hoops, with very trifling differences in hardness between the interior and an outside corner. No piece can be more favorably shaped for heating equally and for rapid and effective cooling than a hollow cylinder, such as a gun-tube, jacket or hoop, especially if treated with an inside circulation, as in recent French methods. No shape can be heated and cooled with less risk of damage to it.

Bridge engineers, instead of ignoring the effects of tempering, would do well to study the subject, for I believe much material is used in bridges that is faulty in condition, and which can be corrected by proper treatment.

It may perhaps interest the Institute to know that there is a concern (the Cambria Company) manufacturing railway axles, a steel product required to stand continuous and severe shocks, that, after study of the best method of making them of uniform condition, has adopted the method of tempering and annealing. And here let me say that this should be called toughening, because steel in which the particles are caught in the proper state and fixed by sudden cooling while they are in this state, is really in the strongest possible condition. It is toughened, and the after annealing will serve to make it as soft as it can possibly be consistent with its analysis. If a concern with reputation to maintain, and with a product to sell for which its reputation is a guarantee, deliberately adopts the method of tempering at increased cost, of finishing that product, this fact says something for the method; and if that process is applied to an amount of steel

production equal in weight to a sixteen-inch steel gun, every week, this also says something for the method. We have proved our ground by experiments which showed the great superiority of the treated axle.

The remarks of the Lloyd's specifications, to my mind, is another misinterpretation of facts. As commercially manufactured, large and small material, thick and thin plates, are made from the same sized ingots or blooms, and the larger bars and thickest plates are very apt to be worked at higher temperature than small bars or thin plates. Hence the same material will show lower elastic limits and ultimate strength in thick pieces. Lloyd's, unable to revolutionize manufacture, provided for this difference, in order that the manufacturer should not increase the carbon in the thick plates to attain the higher ultimate of the lower-carbon, colder-rolled, thin plates.

To meet the point of the damages to steel guns from shot striking them, I will cite the following experiment as a case in point, to show the effect of punishment on gun steel: A rejected ring of which we desired to have a fracture on a large scale was placed under our drop. The ring was twenty inches by four inches section, about thirty inches diameter, and the weight was a new conical-pointed air-furnace cast-iron ball, 4600 pounds, falling forty-six feet. Our drop hands are experts at breaking material up, and placed the ring as favorably as possible. No accurate record was kept, as all we were after was a specimen fracture. After thirty or forty blows from full height of drop, which only resulted in knocking the ring about one-half inch elliptical, we gave the contest up. There was no discoverable crack or break in the hoop, and I have no hesitation in expressing my belief that you might plaster machine-gun shot all over a good steel gun without damage beyond the superficial marks or cuts the bullets would make. Upon this point I would like to hear from some of the ordnance officers.

As to commercial use, hard steel, if this gun material may be called hard steel, is not unknown nor inextensively used. The use of steel tire on the wheels of every locomotive and nearly every first-class passenger car in this land or abroad is well known. The carbon or hardness of tire steel is not less than approved gun steel. We risk our lives upon the safety of such steel every day, and might be willing to risk the lives of our paid military men upon a much more carefully made and selected quality of no harder steel. Rails thirty to forty carbon, axles thirty carbon, and many other things, are by no

means of mild steel. Nor has the experimental use of soft steel for rails proved it safer than higher carbons.

Finally, let us touch the vital point. The author says a gun can be made of low steel. He does not submit a design for such a gun properly proportioned, and until he does submit a design that will stand intelligent criticism, I hardly think he is entitled to a hearing on that side of the case. For reasons well known to even the superficial student of the strains in modern guns, no low-steel gun can be designed to stand high-powder pressure. Unless we abandon the high pressure and the high velocity of the modern steel guns, and with these the low trajectory, great range and penetrative power of these pieces, we must use high steel. Reducing the ultimate strength of steel in tubes and jackets means reducing the amount of compression they will stand with guns at rest, and a similar loss of tensile strength with guns in action, so that this loss of strength acts at both extremes and is a double loss.

As for the hoop system farthest removed from the shocks and subject to the least extension, it would be bad engineering to use a material of less elastic and ultimate, and more ductile, than that in the tubes and jacket. Every system that does this will come to grief.

So far as the hoop system of the guns goes, I can speak from knowledge of my own great confidence in the excellence of the material and in the care of its selection by our officers. I have been unable to find, and doubt if any authenticated case of burst steel hoops exists, sufficient to alarm an engineer of good judgment. Let us carry into this matter a little of the common sense we apply to every-day engineering. This is a question of maximum offensive power against our enemies, and it may even pay to risk the bursting of a gun, if, in doing so, we punch a hole in the enemy's armor and sink his ship. It is a question of effect and its cost.

Our naval vessels must carry artillery giving the maximum penetration and offensive power for the given weight. War is not a safe business, even at the butt-end of a gun, and with good engineering work, done with good judgment, it is the duty of our artillerymen to do the most damage possible to our enemy, taking in warfare at least as much risk as to the strength of structures they use as a good engineer in civil life does with his locomotives and bridges.

Mr. R. W. DAVENPORT, *Superintendent of the Midvale Steel Co., Philadelphia, Pa.—Mr. Chairman and Gentlemen:*—Being very

much interested in the subject now before the Institute, and having been closely connected, in my work at Midvale, with the first efforts looking to the manufacture of steel for heavy guns in this country, I have read with much care Mr. Dorsey's paper, and would like to make a few remarks on the subject from a manufacturing standpoint.

We have all heard with interest the able papers of the gentlemen, representing both the Navy and the Army, who have given the subject of gun construction much study, and no one can doubt but that their conclusions are correct, and that they know what they want, and that if they can obtain a metal for their guns possessing all the good qualities they desire, the problem of safe high-power guns will be practically solved.

The question for us steel manufacturers to consider is, can we make a thoroughly reliable metal that will meet the theoretical demands of the gun constructors? And if not, how closely can we approximate to such results? It is from this point of view that I shall take the liberty of criticising some of Mr. Dorsey's statements and conclusions.

In general, I may say that I feel very sure that if Mr. Dorsey had given near as much study to the subject of gun construction and the manufacture of steel for heavy ordnance as he has to bridge construction and the manufacture and use of structural steel, he never would have made several of the statements or drawn the conclusion contained in his paper. In my opinion his paper shows a great lack of thorough investigation of the present state of the art of manufacturing forgings for guns, and contains a number of statements that are, to say the least, misleading.

I make this general statement with a full appreciation of the truth and importance of what is undoubtedly the leading idea of Mr. Dorsey's paper—namely, that in the desire and efforts of our gun constructors to obtain material possessing a very high tensile strength, and especially a high elastic limit, there *is* a danger of using a harder steel than is thoroughly consistent with maximum safety. I do not mean to say that up to the present time this has been done in the guns constructed in this country—I do not think it has—but simply to point out that such a danger does exist, and that beyond doubt hard steel, and especially large masses of hard steel, require more care in working than does very soft steel under similar circumstances. But, because this may be the case, are there any just grounds for discarding entirely all the admirable qualities and possibilities possessed by

what I may term *medium hard steels* (for hard steels, properly so called, are *not* used in the construction of ordnance), and, without making any effort to avoid and overcome the difficulties that may be inherent in the manufacture of such steels, confine ourselves to the use of a grade of metal which, on the whole, is so poorly adapted to the construction of guns as is the very soft steel which Mr. Dorsey advocates? And it is just here that I think that Mr. Dorsey has been very remiss in not thoroughly informing himself of what has been and is being done to take advantage of the high qualities of medium hard steel, while avoiding the dangers that may, under unfavorable circumstances, exist in the manufacture of the same.

To consider the paper more in detail, I should like to refer to a few points which appear to me to be especially misleading:

1st. In dividing steel into two classes—viz.: mild steel having a tensile strength of from 55,000 to 65,000 pounds per square inch, and hard steel with a tensile strength of over 90,000 pounds—the all-important class lying between these two extremes is entirely overlooked. Now, the fact is that a very large proportion of the metal used for gun construction—namely, that from which the heavy forgings for the tubes and jackets are made—falls within this intermediate class, and has a natural* tensile strength of from 75,000 to 90,000 pounds per square inch and an elongation of from 25 to 20 per cent., measured in eight diameters. It is, in most cases, only the hoops forming the exterior layers of the built-up gun that are made of a steel having a natural tensile strength of from 90,000 to 100,000 pounds per square inch and an elongation of from 20 to 15 per cent., and any one who is acquainted with the modern theory of gun construction will admit that it is not only highly advantageous, but also perfectly consistent with safety, to use a harder steel for the exterior hoops than for the interior tube and intermediate jacket, which first receive the shock of the explosion of the powder and resist in great part the vibratory strains caused thereby.

2d. In dividing steel into two classes, soft and hard, Mr. Dorsey has made use of only one property of the metal—namely, its ultimate tensile strength—and has made no mention of its elastic limit and the *elongation* at the elastic limit. These are the two properties which

* When reference is made to the "natural" physical properties of steel, I mean those properties which are shown by the tensile test of a bar rolled or hammered to one square inch, finished at about a cherry heat, with no subsequent treatment.

are most used by the gun constructor in his calculations, and which he desires to have as great as practicable.

Above all, no mention is made of the total elongation and contraction of area at fracture. Now, these are the physical properties which indicate the ability of metal to resist sudden shock and distortion without fracture, and which, of course, exist in the highest degree in very mild or soft steels; but the question as to what extent these properties can, by proper method of manufacture, be combined with a much higher tensile strength and consequent elastic limit than can possibly exist in large masses of the material which Mr. Dorsey advocates, receives no consideration in his paper. If a material could be produced combining the maximum tensile strength of a tempered hard steel with the total elongation of boiler plate, would it not be preeminently adapted to all structural purposes? And can it be doubted that it must be the aim of every manufacturer of steel for guns to produce a metal in which these properties—*i. e.* high tensile strength and elastic limit, and great elongation and contraction of area—are combined in the highest possible degree?

As an example of what has been attained under favorable circumstances, may be noted the chase hoops for 8-inch and 10-inch guns, made by the Midvale Steel Company, in which an average of twenty specimens four diameters in length, taken from ten hoops, show an ultimate tensile strength of 100,800 pounds per square inch, an elastic limit of 57,000 pounds, a total elongation of 21.94 per cent., and a contraction of area of 43.58 per cent. Also, in jackets for 6-inch guns, an average of twenty-four specimens, taken from four jackets, show 92,000 pounds per square inch tensile strength, 45,500 elastic limit, 22 per cent. elongation, and 41 per cent. contraction, while an average of twenty specimens taken from four tubes for 6-inch guns show an ultimate tensile strength of 82,000 pounds per square inch, an elastic limit of 42,500 pounds, a total elongation of 24.6 per cent., and a contraction of area of 47.8 per cent. It cannot be doubted that the elongations and contractions above given indicate a metal whose ability to resist shock and distortion is very great, and it would certainly be most unwise not to utilize an elastic limit which in the case of the tubes and jackets is nearly as great as, and in the case of the hoops equal to, the tensile strength of the material which Mr. Dorsey recommends.

3d. As regards the oil-tempering of forgings for guns, Mr. Dorsey's remarks indicate an almost complete lack of knowledge, not only of

the generally accepted theories of how the tempering affects the molecular structure of the steel, but also of the real object of such treatment, of the details of the operation, and of the unquestionable proof of the beneficial effect of the same based on great numbers of carefully made tests.

It is *not* generally supposed that the oil into which a piece of hot steel is immersed permeates the mass, exercising some mysterious influence for good, and it is therefore difficult to see why the "compactness" of the metal need be considered. It is generally admitted that the effect of tempering in oil or any other liquid is to *fix* by rapid cooling the amorphous conditions existing in the heated mass, thus preventing the formation of a coarsely crystalline structure, and destroying the irregular and more or less coarsely crystalline condition existing in every forging of considerable size when it leaves the hammer. Oil is used instead of water simply because it cools less rapidly, and therefore the danger of cracking the piece by internal strains is obviated, and tubes and jackets are tempered after boring in order that the oil may pass up through the bore and cool the walls of the cylinder more rapidly. This tempering or rapid cooling of course hardens the steel and increases the tensile strength and elastic limit while decreasing its elongation and contraction; but in most cases this is not the end in view, or at all events only to a limited extent, and the tempering should always be followed by some process of annealing by which the internal strains are relieved and ultimate tensile strength reduced to the point required. By such treatment the elastic limit, as related to the tensile strength and the elongation at the elastic limit, is decidedly increased throughout the mass, and if the piece has been sufficiently annealed to reduce its tensile strength approximately to that of the steel in its natural condition, the elongation and contraction of area of the metal are largely increased. Beside this, the molecular condition of the mass is far more uniform after treatment than before, and while the effect of the tempering decreases as the thickness of the piece increases, it can be assumed that practically uniform qualities are obtained in cylinders whose walls are four inches thick. In this connection it may be mentioned that the failures of the English guns referred to by Mr. Dorsey are without doubt in great part due to the fact that formerly it was not the custom at Woolwich to thoroughly anneal the tubes, or in fact any of the parts, after tempering, and that therefore the elongation and contraction of area of the metal were so reduced by the hardening process used alone that the tubes in partic-

ular were not in a fit condition to resist the shock and vibratory action of the explosion.

4th. From Mr. Dorsey's statements, persons unfamiliar with existing facts would be led to infer that the harder grades of steel were rather uncommon products and difficult and costly to manufacture; this is very far from being the case. In the first place, the steel of which rails are usually made (and more steel is put into rails than into all other products combined) has a tensile strength of from 70,000 to 80,000 pounds per square inch, and in the best quality of rails, where the phosphorus is low, the carbon often runs as high as .4 per cent., which corresponds to a tensile strength of about 90,000 pounds per square inch. Again, locomotive and car-wheel tires, which are made in large quantities by the open-hearth process, and which, for instance, form the principal product of the Midvale Company, are much harder than rails. Thus, of the four grades of Midvale tire steel, the softest has a natural tensile strength of about 100,000 pounds per square inch, with from fourteen to seventeen per cent. elongation in a length of eight diameters, while the tensile strength of the hardest grade varies from 130,000 to 140,000 pounds, with an elongation of from seven to ten per cent. According to the specifications of the Pennsylvania Railroad, steel for axles should have a tensile strength of 80,000 pounds per square inch, and for crank pins 85,000 pounds, while spring steel, with a tensile strength of about 125,000 pounds per square inch, is regularly produced in large quantities by the open-hearth as well as by the crucible process. Many more instances could be cited, but the above are enough to show that the production of *hard*, as well as *medium hard*, steels on a commercial scale is the rule rather than the exception.

5th. I may finally remark that what Mr. Dorsey says regarding the *economy* to be attained by the use of very soft steel for gun forgings is especially misleading, and shows how little he has considered the real causes of the high cost of material for gun construction; one might infer from his paper that it is only necessary to purchase a lot of soft steel rolled into bars of some convenient shape, at $60 per ton, and therewith construct a gun. In point of fact, there would be little or no difference in the cost of the manufacture of forgings from the very soft steel recommended by Mr. Dorsey, or the medium hard steels from which such forgings are made. The question of the cost of the stock or raw material used need not be considered, for the difference in value between the commoner grades

of raw material and the high grades used for making ingots for gun forgings forms so small a percentage of the total cost of producing such forgings that it would be very unwise to attempt to economize in this direction; especially as, in order to successfully meet the specifications, the *best* material is none too good. The real causes of the high cost of the steel forgings required for gun construction are, first, the large loss of material in forging due to scrapping about fifty per cent. of the original weight of the ingot in order to make use of only the best part of same; second, the amount of machine-work required to rough-bore and turn the forgings, and the great loss of weight due to these operations; third, the cost of oil-tempering and annealing; fourth, the extra metal that must be allowed in the length of the forgings for testing, all of which ultimately goes to waste, and the cost of cutting out and preparing test specimens. This expense of testing amounts to much more than would be supposed. Fifth, the rejections due to material not fully meeting the specifications, or to the presence of slight defects, which may only be discovered when the piece is being finished, after provisional acceptance. Now, all the above items of cost would be practically the same, whether a very soft or a medium hard grade of steel be used. In some respects, indeed, as in the operations of melting and casting, where, to make large ingots, the products of several furnaces have to be combined, the costs and risks of production are less in the case of the harder than of the softer steel, while the expense of doing the machine-work on the former would be somewhat greater than on the latter. When, however, it is remembered that, in order to construct a gun of equal strength, a greater weight of the softer than of the harder steel would be required, it is evident that, instead of there being any economy in following Mr. Dorsey's recommendations, there would be a considerable increase of cost. I have only to add that I hope the above remarks, made from a manufacturer's point of view, may help to prove that Mr. Dorsey's attack on the best modern practice in gun construction is entirely unwarranted, and that his data, as well as his conclusions, are unscientific.

Mr. Isaac G. Johnson, *Proprietor Crucible-Cast-Steel Works, Spuyten Duyvil, New York.—Mr. Chairman and Gentlemen:*—In considering the paper from Mr. Dorsey that has just been read, I notice that he treats steel as being of two grades, which he calls "mild" steel, having a tensile strength of 55,000 pounds to the square

inch, and "high-tool" steel, having a tensile strength of 150,000 pounds.

I would call your attention to the fact that steel, instead of being a simple metal, is an alloy, composed not only of metallic elements, but of non-metallic. It is also found to be an alloy of extreme sensitiveness. Its character is determined not only by the elements entering into it, but by the various proportions of those elements, the quality changing as the proportion of the different elements changes. We find in practice that the introduction of a new element in almost homeopathic quantities materially affects the quality of steel.

In our discussion of this matter we wish to consider steel as of two grades, as presented by Mr. Dorsey. In order to determine which of the two grades, as presented by him, is the better suited for heavy guns, we cannot do better than consider the peculiarities of these grades.

The advantages possessed and claimed for mild steel are cheapness and uniformity of product. We cannot do better than attempt to discover why it is that articles made of mild steel are uniform in tensile strength. It has been discovered in working mild steel, either by hammering or rolling, that the bar when first finished is in tensile strength and elasticity far below the standard that might reasonably be expected of it; but it gains in strength and elasticity each hour after rolling, up to the twenty-fourth, inclusive. At that time it seems to gain substantially its maximum strength. The only explanation that can be given of this apparent increase of strength is that, in the last two or three passes which the bar makes through the rolls, the steel is reduced very slightly in diameter, the object being simply to remove the scale and to get a perfect surface. This condenses the steel upon the surface to a slight depth, and is in reality an element of weakness rather than strength to the bar as a unit. But a cold flow of metal sets in, and if the steel is so soft that the particles can move among themselves, in twenty-four hours the steel comes to a state of rest. This cold flow of metal will not take place of itself unassisted in high steel, which I will show later.

One great objection to mild steel for artillery purposes is its extreme softness, and its incapacity to resist friction. The rifle of a gun formed of mild steel would not be durable, and after a few rounds would be unreliable, so that the shot or shell would fail to rotate properly. Mild steel has been found to answer excellently for rolls for rolling "blooms" or "flats" where there was no motion between the ingot

and the roll; but whenever rolls have been made of it for rolling shapes where there was a motion between the ingot and the roll, they have completely failed. I know of a set of rolls made for rolling wire stock, of a diamond shape, of superior open-hearth steel, that lasted only five hours, whereas a roll of ordinary gun metal would have lasted as many weeks. Mild steel has therefore been abandoned for this purpose, and the wear of shot or shell on the rifle of a gun would be similar.

In constructing a gun, I consider that the first requisite is that the steel should be in a state of absolute rest. To show the necessity of this condition of the metal, I will refer you to some experiments that were made with the Delafield gun, which I made in 1861 or 1862. This was a cast-iron gun reinforced with wrought iron, as in Parrott's twenty-pounder of the same size bore. Sixty-four of these guns were made, all of which were tested and proved satisfactory. One was fired a thousand rounds, and then fired with double the usual charge of powder and double shot, without fracture. One of these guns, after being rifled and finished, with the exception of putting on the "reinforce" and turning up the trunnions, was found defective in one of the trunnions, and was therefore never finished. The casting lay in the yard, exposed to summer's sun and winter's cold, for five seasons, and by the expansion and contraction caused by the variation of temperature the particles of iron became absolutely at rest. At that time our engineer's little boy was drowned. The gun was taken to the edge of the dock and fired, with the hope thereby to cause the body to rise. The gun was loaded with an unusually heavy charge of powder, and filled with brick and dirt clear to the muzzle. It lay on the ground, and the recoil was so great that the gun was thrown twenty feet from the position of firing, without any fracture. I would also state that these guns were found to be too light to shoot straight, and three hundred pounds were afterward added to the muzzle.

The only objection that is raised to steel of high tensile strain for guns is the want of uniformity of the articles that are made of it. This want of uniformity is owing to the want of proper care in working or manipulating the steel after it has been cast in the ingot. It is well known that an ingot of high steel can be cast more free from blow-holes than low steel, from the fact that it is more fluid, melting at a lower temperature, and therefore allowing whatever gas may be in the steel a better opportunity to escape from the ingot mould in the process of cooling. The only difficulty arising in its working or

manipulation comes from the fact that where the steel is dense, by increased percentage of carbon or otherwise, the cold flow of metal is prevented by its density, and takes place so slowly that, for practical purposes, it does not exist.

A few years ago the firm of John Robinson & Co., of Brooklyn, received a contract to coat with lead an electrical wire that had previously been insulated with gutta-percha, so that it would present the appearance of being formed in a lead pipe. It was necessary that the lead pipe should be formed around the gutta-percha cold, in order not to destroy the gutta-percha. For this purpose they had a block of steel forged eighteen inches long, twelve inches wide, and about ten inches deep, of the highest grade of steel. In the centre of this block was bored a two-inch hole, into which the lead was cast, allowed to cool, and then by hydrostatic pressure was forced around the electrical wire. As soon as the machine was started, before any great amount of pressure was put on, the block split lengthwise, not resisting the strain as well as ordinary gun metal. The fracture was as straight as, and more uniform than, it would have been in a pine block. This firm, supposing that they had not been dealt fairly with by the parties who furnished the steel, had sections taken from different portions of the block, and found that from one portion of the block they got a tensile strain of 111,000 pounds per inch, and on another portion of the block, not ten inches from where this specimen was cut, they got only 52,000 pounds; showing that, although the block had been forged a month, no cold flow had taken place sufficient to produce a uniformity throughout the block. If the steel had been annealed with sufficient care, its particles would have rearranged themselves and become perfectly homogeneous. On inspecting this block, I found that it was apparently a very nice piece of forging. Great pains had been taken to produce a splendid surface and perfect angles. The block had received undoubtedly an immense number of light blows, in order to present a finished surface, and each blow that the block received which failed to condense the metal equally through and through the entire mass was an element of weakness rather than of strength. The light blows had condensed the steel on the surface to such an extent that it was not in a condition to bear the internal strain of the hydraulic pressure.

I wish to show here that the annealing which I recommend for high steel must be done with extreme care, because it is found in practice that the particles of steel arrange themselves independently

of the grain or fibre given to the mass by the previous hammering or rolling. The grain is dependent upon the chemical affinity of the alloy; therefore it is found in practice that the same grain and tensile strength can be got by skillfully annealing which can be got by first hammering and then annealing; so it would appear that the process of hammering or rolling could be dispensed with, and, in my opinion, it will be in future. One great advantage of getting the grain by annealing is that, if the annealing is carefully done, the grain is perfectly uniform throughout the entire mass, the same as in the old-fashioned cast-iron gun; and by carefully examining a portion of the metal at the muzzle, you can rely upon uniformity throughout the entire gun. This, you know, is the basis of proceeding of the "Terre-Noir" process. One great advantage of this process is the great uniformity of its capacity to resist strain in all directions.

Mr. Dorsey refers to the tensile strength given to steel by immersing it in an oil-bath as wholly superficial, since the effect of the oil is only skin-deep. He is evidently here mistaken, and has not arrived at his conclusions from practical observation, as has been shown in the papers that have just been read. I consider the effect of immersing steel in an oil-bath as purely mechanical.

To show the effects of oil upon steel, I will give you my experience with a steel boiler that I had made of mild steel about ten years ago. We found, after using the boiler for a week, that the plates over the fire began to warp, the boiler was elongated on the bottom, and the tubes consequently began to leak. The makers of the boiler were called in for an explanation, but they failed to discover the cause, and undertook to prevent further warping by introducing heavy braces, without any advantageous effect. After having the boiler examined by various experts without any satisfactory results, it was suggested by an uneducated man that there must be some oil affecting it, as he had noticed some very unaccountable effects produced by the presence of oil in boilers. We opened the handholes of the boiler and made a close examination. We found appearances of oil near the water-line, but no indications of it over the fire where the plates were warped; but we did find a light coating or deposit of carbon. This we traced to the decomposition of the oil that was held by the water in suspension, mechanically. We were using a compound engine with a surface condenser about forty feet above the hot well. The condensed steam, being forced directly into the boiler while hot, thus kept up the circulation. I had a filter constructed which removed the oil,

had my boiler cleaned, and my trouble disappeared. The slight coating of carbon which was found on the inside of the boiler acted as an excellent non-conductor, preventing the action of the water on the steel, and hence the warping or twisting.

Now, when a piece of heated steel is immersed in an oil-bath, the portion of the oil in contact with the steel is immediately decomposed. The steel is covered with a light coating of carbon such as my boiler received, only of much greater thickness, which protects the steel from the further direct action of the oil. The surface of the steel is thereby reduced in temperature, and by its contraction compresses the grain of the steel throughout the entire mass, changing the grain and structure of the steel, making it uniform throughout, provided the steel is of uniform thickness and size. If there are parts of the bar or casting that are of much greater thickness than the adjoining parts, there is liable to be a weak point at the junction.

Captain ROGERS BIRNIE, JR., *Ordnance Department United States Army.—Mr. Chairman and Gentlemen:*—The points upon which I shall mainly take issue with the paper are, first, to show how inaccurate is its conception of the qualities of gun steel, and state in this connection briefly what these qualities really are; second, to enumerate some of the more serious objections to the use of the ordinary mild steel of commerce for making guns.

We have no need to discuss the wide range of the so-called hard steel mentioned. The metal which we use for guns is a relatively low steel, such as the French denominate *acier doux*, seldom containing more than 0.45 per cent. of carbon. It gives, before treatment, an ultimate resistance of from 70,000 to 90,000 pounds per square inch, and by judicious treatment, annealing before and after oil-tempering, its qualities are improved for the purpose of gun construction. It is not capricious or unreliable when properly treated, and I can exhibit specimen bars which were taken in the ordinary course of tests from the interior of forgings and have been bent nearly double when cold without fracture. Besides which, examination of the fractures of the many tensile specimens that have been taken plainly indicates a tough and ductile metal. The arbitrary limit of 90,000 pounds used to fix the border-line of capricious and unreliable steel must be raised much higher, if, indeed, there is any such definable limit for a metal which can be so readily adapted to a wide range of uses in the arts, and can, with proper care in manufacture, such as in

a knife-edge, for instance, be made reliable for its purpose, although capable of resisting a compressive force of about 400,000 pounds per square inch.

When we come to condemn the qualities of any given steel, an intimate knowledge of the circumstances attending its manufacture is essential to determine the cause of the failure. Bad workmanship will make poor material of mild steel or any other kind. On the other hand, we know that in proportion to their facilities steelmakers in our own country can turn out a highly uniform and reliable quality of the gun steel required.

A somewhat intimate knowledge of the tests of the gun steel supplied to the Army Ordnance Department within the past four years enables me to collate some facts which, I believe, will materially relieve the fears of the author and those who may think with him in regard to the nature of the steel we are using.

The hoops were first taken in hand, and two sample hoops furnished by the Midvale Steel Co. were subjected to special tests, besides the specimen tests. These hoops were about forty-five inches interior diameter, four inches thick, and 5.625 inches in length. One, which contained considerably the higher percentage of carbon—over 0.2 per cent. more than I have previously mentioned as the maximum generally used for gun steel—was simply annealed after forging and rolling; the other, a prototype of our present hoop steel, was annealed, oil-tempered and again annealed.

A number of bars were cut from the ends of the forgings, outside, inside and middle, for test. The mean of the three-inch bars—four for each hoop—gave the following:

| | Elastic Limit. Pounds. | Elastic Extension. Thousandths. | Ultimate Resistance. Pounds. | Ultimate Extension. Per cent. |
|---|---|---|---|---|
| Annealed hoop, | 46,260 | 1.50 | 102,500 | 17.85 |
| Oil-tempered, | 56,260 | 2.42 | 99,250 | 19.38 |

The two hoops were fine finished and then heated and shrunk upon a cast-iron cylinder. They remained in this strained position for about ninety hours, during which time the interior of the annealed hoop was stretched 1.68 thousandths, and the oil-tempered hoop 1.60 thousandths per linear inch. The respective tangential tensions on the interiors were about 48,000 and 54,000 pounds per square inch. But on cutting away the cast iron each hoop sprang back very nearly to its original dimensions. The restoration of the oil-tempered hoop was practically complete.

Again the hoops were heated and shrunk upon a cylinder, but this time with double the previous shrinkage. They remained thus for seventy-two hours with their respective interior diameters (or circumferences) stretched 3.137 and 3.0 thousandths per linear inch, or under tangential stress of about 84,000 pounds per square inch for the annealed, and 77,000 pounds per square inch for the oil-tempered hoop. When the cast iron was cut away the permanent set of the annealed hoop was found to be 1.19 thousandths, and of the oil-tempered 1.08 thousandths per linear inch. That is to say, their elastic restoration was nearly two-thirds of the excessive strain which had been maintained for seventy-two hours. Neither hoop exhibited the slightest sign of fracture.

The results of these tests led to the adoption of the naturally softer steel, oil-tempered and annealed, which was proved to be in every way superior to the annealed hoop in elastic power. But in the other hoop we have an example of the capabilities of steel if properly manufactured. The metal had a tenacity of over 100,000 pounds per square inch, and it was not oil-tempered, yet it was splendid material, and was rejected for gun construction only because it was tested beside what was considered a somewhat better steel for gun hoops.

Since these tests were made, some twelve lots, comprising over one hundred and fifty gun hoops, have been accepted. They have all been made of the medium low steel, oil-tempered and annealed, and are at least as good as the sample hoop first tested.

The scope of several subsequent shrinkage experiments was enlarged, to test the accuracy of our theories of gun construction, as well as the qualities of the metal, and the results, I may say, have been highly satisfactory.

One incident in connection with these tests was as follows: After building up by shrinkage a compound cylinder 7.5 inches in length, as an exact counterpart of a section of an 8-inch steel gun over the chamber, it was left undisturbed for several weeks, and at the end of that time was dismantled by cutting off the outside pieces consecutively. Whilst the outer hoop of this section remained in place, its interior was extended 1.14 thousandths per linear unit, corresponding to a tension of over 45,000 pounds per square inch. The hoop was loosened by cutting through lengthwise on one side. It was then sprung open by wedging and removed from the section. Notwithstanding this treatment, the hoop when left to itself resumed exactly its circular form, and showed a permanent extension from its original dimensions of but 0.07 thousandths per linear unit.

An important deduction drawn from all these shrinkage tests is that the elastic properties exhibited by the cylinders as a whole are, within narrow limits, the same as like properties determined by the free tests. In other words, the free tests afford us reliable data for constructing the guns. I conclude that this is due to two causes: first, that the metal is very uniform, and second, that when the cylinders are shrunk together, the strain to which they are subjected is uniform in character for the concentric laminae into which they may be conceived to be divided.

I will now give some examples of the specific effects of the oil-tempering and annealing treatment.* The following, taken from the report of the Chief of Ordnance for 1885, page 453, shows the excellent effect produced upon a plain cylindrical hoop forging for a 12-inch rifle. The interior diameter of the hoop was thirty-nine inches nearly, and its thickness 3.625 inches. The specimens were taken tangentially 1.5 inches from the end faces and were six inches in length:

| | No. of Specimen. | Position of Specimen. | Elastic Limit. | Elastic Extension. | Tenacity. | Elongation after Rupture. | Reduction in Area. | Specific Gravity. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Lbs. | Thous. | Lbs. | Per ct. | Per cent. | | |
| Before treatment | 1 | Inside | 34,000 | 1.333 | 83,600 | 18.33 | 39.2 | 7.8575 | 14.9 |
| | 2 | Outsi'e | 37,000 | 1.367 | 88,000 | 20.50 | 33.5 | | |
| After treatment. | 3 | Inside | 55,000 | 2.100 | 101,660 | 12.5 | 33.5 | 7.8632 | 19.81 |
| | 4 | Outsi'e | 55,000 | 1.833 | 107,160 | 12.83 | 30.6 | | |
| | 5 | Middle | 53,000 | 1.833 | 102,400 | 13.67 | 33.5 | | |

The average qualities of the metal before treatment were: Tenacity 86,000 pounds, elongation nineteen per cent., and reduction of area 36.3 per cent. The effect of the treatment upon the average qualities was to raise the elastic limit, in round numbers, 19,000 pounds, elastic extension 1.9 thousandths, tenacity 18,000, and hardness five per cent., while the elongation was lowered to thirteen per cent., and the contraction of area to 32.5 per cent. only.

* See also Exhibit I. Addenda.

Another example was found in some special tests of a forged trunnion hoop, to which reference will be made, in order to show the outcome of the treatment upon an irregularly shaped and comparatively thick mass of metal. The rough-finished forging, after the ends had been cut off for tests, weighed 2568 pounds. Its interior diameter was 23.25 inches, length 13.8 inches, and average thickness 4.875 inches; whilst on the line of the axis through the trunnion masses the dimensions of solid metal were 12.625 inches. Besides four tangential six-inch specimens taken from each end of the hoop, ten additional ones were taken from a ring cut from the middle length of the forging through the trunnion masses. The actual mean results of the tests of these ten specimens follow herewith in comparison with the minimum requirements of the specifications, which were placed relatively low because the work was experimental:

| | Elastic Limit. Pounds. | Elastic Extension. Thousandths. | Ultimate Resistance. Pounds. | Ultimate Extension. Per Cent. |
|---|---|---|---|---|
| Actual . . . . . | 48,300 | 1.623 | 86,625 | 17.81 |
| Minimum requirements | 42,000 | —— | 88,000 | 12.00 |

This metal was somewhat above the limit in carbon which has been stated, and the good effect of the treatment prescribed may be judged from the fact that two specimens taken from the hoop after forging, but before treatment, showed: Tenacity 103,967 and 104,453 pounds, elongation nine and seven per cent., and contraction 8.2 and 6.28 per cent. The very poorest results obtained from any one specimen of the eighteen taken after treatment were: Elastic limit 46,000 pounds, tenacity 88,960 pounds, elongation 14.5 per cent., and contraction of original area 47.2 per cent. Here, starting with a higher grade of steel deficient in ductility, the treatment reduced the tenacity, but corrected the ductility.

One-half of the hoop was preserved and subjected to shrinkage tests for elasticity and strength like those previously mentioned. In the first, the half hoop was distended to equal very nearly the average limit of elastic stretch determined by the free tests, and its restoration was nearly perfect when the cast-iron cylinder was cut out. In the second test this distension was more than doubled. And in this test, although the final permanent set was more marked on the diameter of the trunnion masses than elsewhere, the average elastic restoration of the hoop on the removal of the cast-iron cylinder was about fifty-five per cent. of the stretch induced by the test.

Many more facts bearing upon the subject might be stated, and in this connection I would refer especially to the results of tests published annually in the reports of the Chief of Ordnance; but I think those already given here will fully support the conclusion that the steel accepted under the specifications mentioned in the paper is not capricious or unreliable and is far superior to the ordinary mild steel of commerce for the purposes of gun construction, for the simple reason, if for none other, that its elastic limit is nearly equal to the ultimate resistance of the mild steel. On the other hand, those specifications are for the plain cylindrical gun hoops only, which form the outer envelope of the gun. And, since the disturbance is inversely proportional to the square of the distance from the centre, the extensibility and ductility of the metal are ample to sustain these hoops much beyond the point at which a gun would become utterly useless by reason of enlargements.

For tubes and jackets, which have to undergo a greater movement, more ductile metal is prescribed. And so on throughout the whole question the various conditions of the problem, founded upon study and the results of experience, are observed.

Having now shown how the steel is benefited for the purposes of gun construction by the treatment—a point which will be emphasized further on—and demonstrated beyond doubt the reliable character of the metal, even in the massive trunnion hoop, I ask the lecturer to kindly furnish us with the data upon which he bases his question about the effect of this treatment. Is his question based upon mere supposition, or is it the result of careful study and investigation? If the latter, then he will perform a very useful service by publishing the details of his experiments, for oil-tempering is now so much used in the treatment of steel for various purposes, that others will be enabled to avoid in the future the paths which led to his failures.

Such experiments in actual firing of guns as we have been enabled to make in the short time that has elapsed since the present line of inquiry was instituted, and with the means at disposal, have given no reason to doubt that the guns we are now making or propose to make will prove other than strong and enduring. The basis of our knowledge is the large experience of foreign nations and gunmakers, who have experimented with guns of various grades of steel, including very mild steel, in the line of the propositions of the present paper, and have finally settled down to adopt the medium low steel, which is substantially what we use in exercising, however, a very rigid and necessary inspection prior to acceptance.

As long ago as 1873, in deference to the opinions then held by Mr. Schneider, an important series of experiments with mild and medium low steel were made at Creuzot, in the interests of the French Government (*Revue d'Artillerie*, Nos. for July and August, 1874).

Short tubes closed at both ends, and guns also, were subjected to powder tests and extreme firing. The steel ranged from a very mild grade containing 0.155 per cent. of carbon, to a medium grade containing 0.3375 per cent. I quote from the conclusions as follows:

"The hardest steel gave the most satisfactory results, and we should, therefore, give it a preference, although tempted to believe that steel of even a little greater hardness would better respond to the conditions that a good metal for guns ought to fulfil."

The metal which gave the best results had an elastic limit of 33,000 and an ultimate resistance of 74,000 pounds per square inch, combined with an extension of but nine per cent. It contained the highest percentage of carbon in the list, and was oil-tempered.

Do the proprietors of Creuzot now recommend the use of the ordinary mild steel of commerce for making guns, and shall we go back thirteen years in progress?

The opponents of tempered steel for guns cannot take great comfort from the recent failures of English guns. We know, for instance, regarding the Collingwood gun, that the tube forging alone failed, and it was the unhooped portion of the chase which burst. Also, that the forging was made some years since, and was not annealed. Gunmakers learn from such failures that their guns should be hooped to the muzzle. And, although we do not practise such negligent treatment of our forgings, those of our manufacturers and others who think the Government requirements too rigid may well take a lesson from such failures.

There are many reports and contradictions concerning the bursting of steel guns made abroad, yet Mr. Krupp deliberately wrote in 1878 (page 791 Jean's "History of the Manufacture and Uses of Steel," London, 1880) that, of the 17,000 of his guns made since 1847, only eighteen had failed, and those mainly in experimental firing to extremity, or on account of the square angles in the slot made for the breech block, which defect he had remedied. No doubt he excluded from this list a mention of guns in which the breech mechanism had become temporarily disabled; but he was not then, nor are we now, discussing the question of breech mechanism.

I have made no mention of the work of our own Navy, because

those gentlemen are present to speak for themselves, but I tender them hearty congratulations upon the splendid progress they have made.

The lecturer advises the use of the ordinary mild steel of commerce for making guns. It has, he says, a tenacity of from 55,000 to 65,000 pounds per square inch; but from another part of his paper we learn that if a plate (or forging?) is more than three inches thick, the *maximum* tenacity would be below 55,000 pounds per square inch, and this tenacity would continue to decrease at a rapid rate with an increase of the thickness of the plate. It would be perfectly proper to argue from this that plates greater than three inches in thickness cannot be made from mild steel, since near this point the tenacity places the metal below the minimum limit used to define mild steel.

It is reasonable to suppose, however, that with an expenditure of the requisite amount of money and brain-work, the manufacturers could turn out the large forgings of this mild steel quite uniform in character and of a tenacity indigenous to that grade of steel, or, let us say, 60,000 pounds per square inch; but that would be a different affair from the present cheap production. Now, this steel cannot be commended for gun construction by virtue of its tenacity as against another steel having a tenacity of, say, 90,000 pounds per square inch. Then it comes to this—that the great virtue of the mild steel lies in its ductility and a capacity to hold together, and to bend or bulge without fracture when heavily strained. There is also claimed for this steel the property that it is incapable of taking temper.* These may be excellent qualities for the purposes of the bridgebuilder, boiler-maker or architect, but they hardly serve the purposes of the makers of springs, tires or guns. The chiefest merit of the metal constitutes a most serious objection to its use for these purposes. It is true we require great strength in a gun, but that is a secondary consideration to precision. A quick falling off in the accuracy of shooting of the gun, due to deformation, is a calamity only less in degree than the bursting of a gun, because it would not endanger the lives of the cannoneers, but it would, just the same, defeat the purpose for which guns are made.

Then, too, the increased dimensions and weight necessary to make a sufficiently strong gun of steel of low tenacity would entail expense and many difficulties. The transportation of the piece, facility

* Competent authorities state that no steel is wholly incapable of taking temper.

and expense of manufacture and of installation of heavy guns, all impose on the gunmaker the necessity of limiting weight, of simplifying construction, and of economizing material to the minimum required to withstand the action of the charge to be used in producing the effect sought.

A gun is essentially an instrument of precision. An ideal gun, in the sense we are now considering, would constitute one great compound spring, responding stiffly to the pressure of the powder gases and then resuming precisely and invariably its original dimensions.

The quality of spring, or, more correctly, elasticity, is so essential in a gun, and the knowledge that it is expedient to temper steel in order to develop this quality is so universal, that it is in the nature of a last resort and a decided step backward to advocate the use of a grade of metal which is incapable of taking a temper and naturally possesses a low elastic limit.*

It is the marked superiority of steel over other commercial metals in respect to strength, stiffness and extensibility, and of the included attributes, especially elasticity, which renders it the fittest of them all for making accurate-shooting, strong and enduring guns, at least in the large calibres.

Gunmakers, then, in order to properly utilize the inherent qualities of this metal, aim to produce a steel which will possess the highest degree of elasticity and tenacity compatible with a requisite extensibility and ductility, and thereby insure an absence of brittleness. It is safe to assert that the ideal gun I have mentioned can never be made; but we should not deliberately neglect to utilize the qualities of steel

* I do not know, in considering the remainder of his paper, what the lecturer means by saying in regard to hoops that by putting on work the tensile strength can be raised very high. I do know that there are earnest advocates of cold rolling or working, but then the lecturer cannot expect to cheapen much the cost of guns if this method is adopted, nor can he apply it to the enormous forgings required for the body of the gun.

By cold working the elastic limit of the hoop metal would be raised very high, but its ultimate extensibility would be reduced to possibly dangerous limits. Dr. Woodbridge states ("Notes on Construction of Ordnance," No. 3, Washington, July 20, 1882), concerning a series of tests made at the Washington Navy Yard, "The steel had, when thoroughly annealed, an elastic limit of strain equal to 40,744 pounds per square inch, and a tensile strength of 71,530 pounds, with an extensibility, in a length of 2 inches and a diameter of 0.5 inch, of 30 per cent. After cold hammering under blows acting upon only one pair of surfaces, its elastic limit of strain became 78,940 pounds, its tensile strength 86,580 pounds, with an extension of 14 per cent."

which enable us to approach that ideal, and, as I have before said, we could only drop now into using the ordinary mild steel of commerce as a last resort. In fine, experience shows us that we should not so lower our standard.

All calculations for the strength of built-up steel guns must, for safety, be based upon the elastic strength of the metal. No member of the structure should be strained beyond its elastic limit either in making or in using the gun, else incipient deformation will be begun, to end in inaccurate shooting and undue enlargements or rupture under continued firings.

The bore of the gun should resume its original form after the firing. Here again our ideal is not attainable in practice. It is quite certainly established that metals can receive some permanent set from strains much below our so-called elastic limit, although this is less apt to occur under sudden strains, such as are due to the firing of a gun, than under long-continued strains. Moreover, there are parts of the bore, especially about the seat of the shot, which are apt to be abnormally enlarged, due, probably, in the main, to the mandreling action of the shot-band. But we adopt for the elastic limit of the metal that point of strain* beyond which the momentary displacements cease to be nearly directly proportional to the stresses, and where an appreciable permanent set is observed in the test specimens. Then the guns are put together with all practicable nicety, and so proportioned as to give a fair margin of elastic strength above anticipated powder pressures. We rely, then, upon the principle that the strains to which the different parts of the gun are subjected will shortly adapt them to withstand, without further material change of form, any strain inferior to the highest which preceded it.

The value of a steel for gun construction, assuming that it possesses the other necessary qualities, is, therefore, dependent upon its elastic limit. And if we use soft steel, we ought, at the least, to provide the same margin of elastic strength as in the case of harder steel.

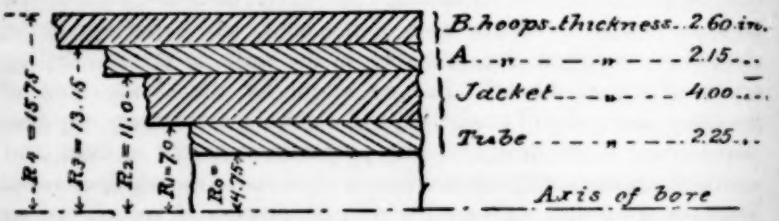
Such expressions of opinion as that a gun may be of "greater theoretical strength, but practically much weaker," need to be very carefully considered before they are enunciated. There exists to-day no more eminently practical profession than that of gunmaking, and none, also, in which the accepted theories have been more rudely or

* Commonly expressed in terms of the stress or the load per square inch which determines this limit of strain.

more crucially tested. No theories are accepted by gunmakers until they have been proved or modified to be consistent with practice.

In order to compare the elastic strength of a gun made of the ordinary mild steel of commerce with one made of gun steel, I shall assume that the mild steel for the whole gun, including the heavy forgings, will possess a uniform tenacity or ultimate resistance equal to 60,000 pounds per square inch, and take the weight modulus of elasticity at 29,000,000 pounds, and the elastic limit at 29,000 pounds or about fifty per cent. of the ultimate strength. The limit of elastic strain will then be 1.0 thousandths of the linear unit.

The following figure shows the radial dimensions of the principal section—*i. e.* the chamber—of an existing 8-inch steel gun which has been fired twenty-four rounds at the Sandy Hook Proving Ground. It is this gun, I believe, to which the lecturer refers in his remarks about thick hoops.




The section in the gun as made is calculated to support without change of form, tangentially, an interior pressure of nearly twenty-five long tons per square inch.

In actual firing it has been subjected to pressures of about sixteen long tons, and the present maximum enlargement near the breech is 0.002 of an inch (on 9.5 inches). In the forward portion of the chamber there is no change. The gun is designed to use a charge which will give a chamber pressure of sixteen tons per square inch. It has, therefore, a margin of fifty-six per cent. of elastic resistance. Now, suppose this gun were made of mild steel. Its elastic resistance would be only fifteen long tons, or two-thirds of what we now have. And to preserve its form equal with that of the present gun we would be compelled to reduce the powder pressure to 9.6 tons per square inch, with a loss of over 200 feet of the present velocity obtained with the standard 285-pound projectile and some 1460 foot-tons of energy at muzzle. I do not doubt that a gun could be made of the mild steel with the same margin of elastic resistance as the present gun,

but the weight would be increased from fourteen to about nineteen tons, roughly estimated.

An embarrassment concerning exact deductions as to weight, etc., arises from the uncertainty left in one's mind as to the design of the guns which the lecturer would propose to build. His propositions are exceedingly indefinite upon that point. However, there would be, probably, a large forging to carry the breech block and support the longitudinal strain, which must be distinguished from the tangential resistance already discussed.

The cross-section of the jacket cylinder in this gun (see figure) is 226 square inches, somewhat less than three times the cross-area of the chamber. The pressure in the chamber may reach 40,000 pounds per square inch, and this would place a longitudinal stress, supposed uniform throughout the section, of 15,800 pounds per square inch upon the jacket. This is about one-third the elastic limit of the metal. For the mild steel, with 29,000 pounds elastic limit, the stress should be similarly limited to, say, 10,000 pounds per square inch. The cross-section of the jacket should then contain 283 square inches. There results an increase of twenty-five per cent. in the area, which, in view of the expense attending the manufacture of large forgings, is a very serious objection, and becomes more so when we consider the proportionate increase of a forging for a sixteen-inch gun, which, if made of gun steel, should be nearly four feet across. At all events, the ordinary mild steel of commerce could not be used at all in such forgings if its strength fall off as indicated by the lecturer in his quotations from Lloyd's Register.

The statement that "the strength and reliability of a gun will increase *for the same weight proportionally as the thickness of the hoops decreases* to a practical limit," is misleading, and, if carefully considered, is found to be not true. It would be true only in case all hoops two inches thick, for instance, could be made only a little more than one-half the strength per square inch of all hoops one inch thick, and this presents an absurdity on its face. For we know that if the manufacturer has facilities to put the necessary amount of work on a hoop even four inches thick, he can make it practically uniform in quality with a hoop one inch thick.

Taking a given case, if we double the number of hoops the increase of strength will be very small. I give an example: Substitute four hoops for the two on the eight-inch gun (see figure previously given). The interior radius of the zone embracing the two hoops is 11.0 inches and the exterior radius 15.75 inches. In dividing the thickness

for four hoops we follow the rule that each radius shall be a mean proportion between the two adjoining ones, and find the values to be:

$R_3$=11″.0, $R_2$=12″.03, $R_1$=13″.16, $R_0$=14″.4 and $R_{-1}$=15″.75.

Proceeding from within outwards, the thicknesses are 1.03, 1.13, 1.24 and 1.35 inches.

Assuming all the hoops to be of mild steel having an elastic limit of 29,000 pounds per square inch, the four hoops properly combined by shrinkage would safely support an interior pressure of 5.55 tons per square inch, and the two hoops combined would similarly support a pressure of 5.15 tons per square inch; or, the difference in favor of the four hoops amounts to but 0.4 of a ton, or 900 pounds per square inch. By way of comparison I will observe that the two hoops actually used on the gun can support within their elastic limit an interior pressure of 9.25 tons per square inch.

I fear the lecturer has, perhaps unwittingly, conveyed an erroneous impression to the uninformed in mentioning the thick hoops of the Ordnance Specifications. The thick hoop he mentions was designed for a special purpose in the construction; its thickness is not uniform in finished dimensions, but the maximum is four inches. For the rest, the hoops of this gun (numbering thirty-four in all) are thinner than will usually be found in guns of this calibre.

I will not be understood as advocating thick hoops. It is easier to produce comparatively thin hoops of uniform quality, and there are advantages to be gained in reliability in using them, but not in any such quantity as the lecturer proposes. Moreover, with such a number of hoops the cost of manufacture would be prodigious, and the risk of spoiling a gun by bad shrinkages greatly increased.

In some experiments made not long since in England, it was found that a 6-pounder Hotchkiss shell fired against the chase of a 9.2-inch steel gun at very short range, produced very large bulges in the bore. The danger of this happening would be increased if the gun were made of the mild steel. As to the effect of small shot on the guns, I think the misapprehension under which the lecturer labors concerning the qualities of gun steel has led him to erroneous conclusions. Guns should be placed under cover when practicable; but if I were to propose, for instance, to sheathe the necessarily exposed parts with some material better adapted than steel to make them bullet-proof, it would constitute no argument in favor of making the whole gun of the same material. What takes place within the gun is of transcendent importance compared to the pattering of small shot upon its exterior. On the other hand, if a dangerous shot should strike the

chase, or a small shot enter the bore, it would be more likely to injure a piece made of the mild steel than one made of gun steel.

The propositions of the lecturer involve a radical improvement in the methods of manufacture of the ordinary mild steel of commerce to make it sufficiently uniform for the heavy forgings, also largely increased sizes of forgings and increased weight of gun. They involve the use of many and thin hoops, which would largely increase the cost and difficulty of manufacture. And they involve the prosecution of enough experiments to determine by empirical means alone the proper thickness of these multitudinous hoops with thicknesses varying for the size and use of the gun. On the question, then, of cost alone, gun for gun, it may well be doubted whether the propositions of the paper would, if carried out, bring about any reduction of present prices.

I need not argue to prove that when steel is required for making guns in quantity the metal should be of home production; patriotism demands this, and it is a military necessity. The gun steel we now produce, although limited in quantity, is excellent in quality and compares most favorably with the best of foreign products. This point has been reached by the independent action of energetic and intelligent steelmakers who have followed up this industry in response to the calls of the Department. We cannot depend upon foreign markets for our gun steel, and therefore, instead of trying to throttle the youthful industry in our own country, we should by all just means encourage its development.

Our standard specifications for gun steel conform to-day to qualities which the Midvale Steel Company and Cambria Iron Works have shown their ability to produce in almost if not quite their first attempts. The same high standards should be maintained, subject only to such interdependent modifications as further experience may teach us will render them more appropriate to procure the grades of steel required. These specifications omit any requirements as to chemical composition and leave a fair field for different manufacturers to reach the standard in their own way.

Our national policy is defensive, not aggressive; yet in providing means of defense we must at least equal and should endeavor to surpass the arms that may be brought against us. Let those who design and make boilers be satisfied, if they will, with the ordinary mild steel of commerce, but do not retard progress and discredit our national intelligence by advocating at this late day the use of such steel for guns.

## ADDENDA.

### EXHIBIT I.—*Tests of Gun Steel before and after Treatment.*

Below will be found a table showing the effect of annealing or of oil-tempering and subsequent annealing on several steel pieces manufactured by the Midvale Steel Company for the Department. The results given are from tests made by the Company. It is to be regretted that their testing machine does not determine the elastic limit.

| NATURE OF PIECE. | TREATMENT. | Results of Test before Treatment. | | | Results of Test after Treatment. | | |
|---|---|---|---|---|---|---|---|
| | | Ultimate resistance per square inch of original section. | Elongation after rupture. | Reduction in area after rupture. | Ultimate resistance per square inch of original section. | Elongation after rupture. | Reduction in area after rupture. |
| | | Pounds. | Per cent. | Per cent. | Pounds. | Per cent. | Per cent. |
| Tube for 3.2-inch rifle | Annealed | 100,500 | 10.5 | 15.6 | 87,700 | 16.0 | 20.0 |
| Tube for 8-inch converted rifle | " | 80,400 | 9.0 | 8.0 | 71,500 | 25.5 | 39.7 |
| Jacket for 3.2-inch rifle | Oil-tempered and annealed | 95,068 | 12.5 | 13.0 | 102,900 | 14.5 | 22.0 |
| Hammered hoop for 8-inch rifle | " " " | 88,900 | 20.5 | 33.0 | 106,600 | 17.5 | 35.0 |
| " " " " | " " " | 94,100 | 19.5 | 32.0 | 102,000 | 20.5 | 47.0 |
| Rolled hoop for 8-inch rifle | " " " | 89,500 | 21.5 | 31.0 | 100,200 | 17.5 | 35.0 |
| Rolled hoop for 12-inch mortar | " " " | 97,500 | 21.0 | 28.7 | 107,000 | 18.0 | 40.0 |
| Rolled hoop for 8-inch rifle | " " " | 89,000 | 18.5 | 27.0 | 107,000 | 19.0 | 39.0 |
| Hammered hoop for 8-inch rifle | " " " | 97,000 | 22.0 | 28.0 | 106,000 | 20.0 | 41.0 |
| Breech block for 12-inch rifle | " " " | 86,132 | 11.5 | 12.0 | 97,720 | 15.0 | 31.0 |
| Breech block for 10-inch rifle | " " " | 84,880 | 24.0 | 41.0 | 94,880 | 20.0 | 41.0 |
| Lever for 12-inch rifle | " " " | 88,400 | 20.0 | 37.0 | 86,920 | 24.0 | 48.0 |
| Spindle for 12-inch rifle | " " " | 103,813 | 5.5 | 5.2 | 97,500 | 17.5 | 29.0 |
| " " " | " " " | 95,820 | 13.0 | 13.0 | 94,700 | 19.0 | 40.0 |
| Rolled hoop for 10-inch rifle | " " " | 85,780 | 22.0 | 34.0 | 101,160 | 19.0 | 34.0 |

NOTE.—The above is an extract from report of Lieutenant F. E. Hobbs, Ordnance Department United States Army, Inspector at the Midvale Steel Works, August 20, 1884. See Report of Chief of Ordnance, United States Army, 1884, page 430.

R. B.

## EXHIBIT II.—*Tests of Gun Steel, Oil-Tempered and Annealed.*

Each one of the following sets of results represents some piece which has been accepted and received by the Department, and they include tubes, jackets, cylindrical hoops and trunnion hoops, the specimens being taken at different points of the thickness of the piece, and generally at least 1½ inches from any surface of the piece. Single specimens can be found giving ideal results, but such would not be a fair example. These given are neither the best nor the worst on which material has been accepted.

| NATURE OF PIECE. | TREATMENT. | Results of Test after Treatment. | | | |
|---|---|---|---|---|---|
| | | Length of specimens. | Elastic limit. | Ultimate resistance. | Elongation after rupture | Contraction of area. |
| | | Inches | Pounds. | Pounds. | Per ct. | Per ct. |
| Hoop for 8-inch steel rifle... | Oil-tempered and annealed | 3 | 59,000 | 103,080 | 17.33 | 36.4 |
| " " " ... | " " " | 3 | 59,000 | 103,120 | 17.67 | 36.4 |
| " " " ... | " " " | 3 | 60,000 | 101,840 | 18.00 | 39.2 |
| Hoop for 10-inch steel rifle... | " " " | 6 | 57,000 | 100,240 | 15.33 | 39.2 |
| " " " ... | " " " | 6 | 56,000 | 100,560 | 17.4 | 45.2 |
| " " " ... | " " " | 6 | 54,000 | 98,520 | 14.7 | 29.5 |
| " " " ... | " " " | 6 | 64,000 | 110,040 | 15.5 | 47.2 |
| " " " ... | " " " | 6 | 62,000 | 110,320 | 14.5 | 35.8 |
| " " " ... | " " " | 6 | 65,000 | 111,480 | 16.0 | 33.3 |
| " " " ... | " " " | 6 | 68,000 | 112,760 | 15.0 | 33.3 |
| Hoop for 12-inch B. L. mortar | " " " | 6 | 57,000 | 106,440 | 12.67 | 39.2 |
| " " " | " " " | 6 | 58,000 | 104,120 | 14.60 | 37.8 |
| " " " | " " " | 6 | 55,000 | 100,240 | 14.00 | 42.8 |
| " " " | " " " | 6 | 58,000 | 105,880 | 11.67 | 40.5 |
| " " " | " " " | 6 | 58,000 | 103,000 | 17.0 | 49.7 |
| " " " | " " " | 6 | 59,000 | 101,200 | 13.0 | 52.2 |
| " " " | " " " | 6 | 59,000 | 104,240 | 15.0 | 49.7 |
| " " " | " " " | 6 | 59,000 | 105,560 | 13.83 | 44.6 |
| Tube for 3.2-inch steel rifle... | " " " | 2 | 54,000 | 94,600 | 26.5 | 43.3 |
| " " " ... | " " " | 2 | 53,000 | 91,900 | 23.5 | 43.3 |
| " " " ... | " " " | 2 | 49,000 | 86,450 | 25.0 | 51.9 |
| " " " ... | " " " | 2 | 49,000 | 88,800 | 21.0 | 43.3 |
| " " " ... | " " " | 2 | 54,000 | 96,600 | 25.0 | 49.1 |
| " " " ... | " " " | 2 | 53,000 | 94,000 | 26.0 | 49.1 |
| Jacket for 3.2-inch steel rifle | " " " | 2 | 48,000 | 88,150 | 28.0 | 51.9 |
| " " " | " " " | 2 | 51,000 | 90,700 | 25.0 | 49.1 |
| " " " | " " " | 2 | 50,000 | 88,050 | 29.0 | 51.9 |
| " " " | " " " | ... | 55,000 | 97,500 | 21.0 | 43.2 |
| " " " | " " " | ... | 54,000 | 97,550 | 24.0 | 46.7 |
| " " " | " " " | ... | 53,000 | 94,700 | 19.5 | 39.2 |
| Tube for 8-inch converted rifle | " " " | 3 | 49,000 | 86,840 | 23.33 | 49.7 |
| " " " | " " " | 3 | 51,000 | 90,400 | 20.0 | 52.2 |
| " " " | " " " | 3 | 46,000 | 86,200 | 21.0 | 52.2 |
| " " " | " " " | 3 | 41,000 | 77,780 | 25.0 | 54.6 |
| " " " | " " " | 3 | 45,000 | 83,000 | 24.33 | 44.6 |
| " " " | " " " | 3 | 42,000 | 78,640 | 27.0 | 54.6 |
| " " " | " " " | 3 | 49,000 | 89,040 | 20.33 | 47.2 |
| " " " | " " " | 3 | 44,000 | 81,680 | 26.33 | 49.7 |
| " " " | " " " | 3 | 47,000 | 90,160 | 20.00 | 39.2 |

NOTE.—The above results were compiled by Lieutenant F. E. Hobbs, Ordnance Department United States Army, Inspector at the Midvale Steel Works and Cambria Iron Works, from recent fabrications. R. B.

At 11 P. M. the Chairman took the floor and called attention to the lateness of the hour, asking the sense of the meeting with regard to continuing the session. Lieutenant Ingersoll moved that Lieutenant Austin M. Knight, U. S. N., be invited to read his paper. The motion was seconded and carried.

Lieutenant AUSTIN M. KNIGHT, *U. S. N., in charge of Naval Proving Grounds, Annapolis, Md.—Mr. Chairman and Gentlemen:* —The writer of this paper comes before the Institute and the public as a civil engineer of ability and established reputation. He speaks from experience and with authority upon the use of steel for bridges, for boilers and for shipbuilding. To his assertions regarding the qualities of steel best suited for these purposes, officers of the Army and Navy will take but little exception. It is not with such applications of steel that their experience or their studies qualify them to deal. Conversely, it seems not unfair to remark that the experience and studies of a civil engineer, unless they have taken a direction outside the ordinary lines of his profession, do not qualify him to speak with special authority upon the construction of ordnance.

That the present lecturer's experience and studies have not taken such exceptional direction, seems clear from this paper. The quality by which alone he defines steel—its ultimate breaking strain—is one of primary importance to the civil engineer, but of altogether secondary importance to the gun constructor. So much is this the case, that by some manufacturers the ultimate tensile strength is entirely disregarded in the acceptance of steel, the elastic limit and elongation being alone considered. By those manufacturers who demand a specified tensile strength, far less weight is attached to it than to the elastic limit, and *percentage of elongation within that limit.*

Again, the sole authority cited by the lecturer is the Chief Engineer of the English Lloyd's, whose opinion about steel would naturally have greater weight with a civil engineer than with a designer or manufacturer of ordnance. And even from this authority he gives us, not an opinion as to the material of which guns should be built, but only a specification for boiler plates and stays. Now, it may be possible to establish an analogy between the strain upon a gun and that upon a boiler, but certainly the analogy is not apparent, and no attempt is made to establish it in this paper. Instead of accepting such a specification, from such a source, as a guide to the design and

construction of ordnance, officers having this work in charge would, I should suppose, look rather to the practice of those large establishments whose needs are similar to their own and whose experience has been with steel, not in small plates and bars, but in such masses as those in which it is to be used for guns. Such establishments are those of Sir Joseph Whitworth, of Firth, of Schneider, of Krupp; at Terre Noire and at Aboukhoff. Every one of these establishments, except the last-named, is engaged in the manufacture of guns or gun steel as a commercial enterprise. Their work is in the market of the world, seeking recognition and a financial return for immense sums of money invested. The failure of a single one of their guns has an immediate and marked effect upon the demand for similar guns. Government ordnance officials may, in some cases, be wedded to theories or methods which are not the best; but the firms enumerated above can have no other aim than to produce the best possible article. They command unlimited capital and can secure the highest ability of the world in their scientific experts. They have had years of experience, during which we may be sure they have not failed to look closely into the cause of every accident that has occurred to their own or other guns. Nor are they likely to have omitted any tests by which the effect of the processes upon which they rely—whether oil-tempering, annealing, or any others—could be determined. These establishments are unanimous in the belief that the material which the lecturer utterly condemns for gun construction is the very best material for that purpose. Surely, their testimony and practice, based as it is upon actual experience, not with ships and bridges, but with guns, should more than offset the latest specifications of Lloyd's Register for boiler plates and stays.

The present discussion is practically a renewal of the old contest of twenty years ago between wrought iron and steel; a contest which ended about 1870 in the decisive victory of steel. An eminent American civil engineer, Mr. Alexander Holley, who, to the familiarity with these metals due to his experience as an engineer, added that derived from special investigation of the subject of ordnance and armor, wrote of that controversy as follows: "Mr. Anderson, Sir William Armstrong, Mr. Mallet and others, complain, in various public statements, that most of the steel they have experimented with for guns is too brittle; that it gives way under *sudden* strains which wrought iron will stand. Hence steel—especially high steel—has been condemned as a cannon metal.

"In answering this objection, let us briefly review what has been said under the head of 'Ductility.' Suppose two thin tubes of equal size, one of high steel and the other of wrought iron, to be subjected to the violent and sudden strains of gunpowder. The elastic limit of the steel is overcome and it soon breaks, because it has but a small reserve of ductility to draw upon to eke out its integrity. The elastic limit of the wrought-iron tube is overcome much sooner, but it has an immense capital of ductility to expend, and so it stretches and stretches for a long time without fracture.

"Now, suppose the quantity—thickness—of steel to be increased just so much that the pressure will never overcome its elastic limit; that is to say, so that its particles will return to their original position after the pressure ceases. Its original resistance to the next strain is then unimpaired, and there is no evidence that it will ever become impaired.

"But, in order to bear the same pressure, the iron, equally increased in quantity, will stretch beyond its elastic limit, and therefore must depend upon a new arrangement of particles and a new limit of elasticity for continued cohesion. Its great ductility allows this rearrangement to continue for some time; but, although it may stretch to a less distance at each renewed application of the pressure, its ability to stretch and its range of elasticity are constantly diminishing, until it at last arrives at a point where it can stretch no further without fracture. It has exhausted its reserve ductility. If it were not so, iron would never be broken at all by stretching.

"This explains the failure, after short service, of thin tubes made of the moderately high steel heretofore used, while thin iron tubes *appear* to be unimpaired by elongation, although they certainly are impaired from another cause—compression. It is simply a question of excess of metal and, practically, endless endurance on the one hand, and ultimate failure on the other hand."

The steel referred to in the above extract had a tensile strength of from 90,000 to 120,000 pounds.

The lecturer believes that steel of this tensile strength cannot be made reliable and uniform; that it is and must be treacherous. In this, as we have seen, he differs from nearly every firm in the world which has had experience in the manufacture of steel in large masses. Those firms claim that the grade of steel in question can be made of practical uniformity and reliability, though recognizing the fact that its production presents certain difficulties and calls for delicate manipu-

lation and for special treatment after manufacture. If their claim be established, the whole argument against such steel falls to the ground. The question can be settled only by experience.

Whitworth and Krupp have been using their present grade of steel and their present system of construction for about fifteen years; the English, French and Russian Governments for a time considerably less. Of the total number of guns manufactured by them all—a number which must amount to several thousand—some five or six have failed in such a way that the failure may have been due to defective steel.

It is true that a large number of Krupp guns were rendered unserviceable by their own fire during the Franco-Prussian War. But this had nothing to do with the steel of which they were composed. The failure was in the breech mechanism. On page 83 of a "Treatise on the Construction and Manufacture of Ordnance," prepared in the English Gun Factory and published in 1877, is the following note, doubtless from the same authority that the Duke of Cambridge quoted in the House of Lords, as mentioned by the lecturer: "The complication due to the breech arrangement was in fact severely felt during the war of 1870–71, when over 200 guns were rendered unserviceable in the field through the breech mechanism becoming defective." The same work gives a list of steel guns which had exploded between 1860 and 1877, from the information in the possession of the English Government. No mention is made of any such accident to a Krupp gun during the Franco-Prussian War.

The Krupp gun, however, of the period up to the close of that war, has but little connection with the present subject, as it was not a built-up gun. It was made from a single ingot of steel, cast and forged, and *not* oil-tempered. When Mr. Krupp—then as now the most extensive manufacturer of, and experimenter with, steel in the world—found reason to believe that his guns could be improved by a change of construction, he lost no time in making the change, but passed at once to the system of building up.

Is it not a significant fact that, with all his knowledge of steel, and considering the radical change he was making in his guns at that time, he found no reason to reduce the tensile strength of his steel, which was then, as now, about 100,000 pounds?

In this country we have lately begun the construction of ordnance from steel similar to that used by Whitworth and Krupp. Our manufacturers took up the matter of producing this high grade of

material with limited facilities and no experience. Twelve guns built for the Navy and one built for the Army have thus far been tested. Of the Navy guns the first one was in use for experimental firing with powder and projectiles during sixteen months. In that time it fired 274 rounds, many of them with pressures from thirty per cent. to fifty per cent. higher than the pressures which it and similar guns will have to endure in service. Two of the others have been publicly subjected to an extreme test of rapid firing with the maximum charges allowed for service. In the bores of two of the others loaded shells have exploded at points near the muzzle—the very weakest part of the gun. The remaining guns of the twelve have been tested with full charges and with pressures exceeding those of service. Several of these have fired more than 60 rounds. No failure of any kind has occurred with any of these guns, nor has the slightest evidence of weakness been revealed.

I submit that this does not look as if the material of which they are composed were hopelessly treacherous, and liable to fly in pieces without apparent cause and when subjected to little or no pressure.

The fact is that the record of modern steel guns of the present system of construction, instead of being, as the lecturer assumes, a record of failure, is one of great and remarkable success. In that record is found the best possible experimental proof of the efficacy of those processes whose value the lecturer thinks so doubtful. In their belief in the value of those processes, gunmakers are not alone.

Prof. R. H. Thurston, in a recent work on "The Materials of Engineering," after speaking of the importance of annealing steel to relieve internal stresses, adds, "Masses of steel may be successfully tempered in oil." Mr. Holley, throughout the work which has already been quoted, constantly refers to the value of oil-tempering for large masses of steel, without intimating a doubt that its effect extends throughout the mass.

With regard to those guns which have failed apparently through the treachery of the steel, it may perhaps be questioned whether the explanation of their failure lies in an overestimate of the strength of the material or an underestimate of the strain which the material would have to stand. It seems to me that in some cases the manufacturers of powder and the manufacturers of guns have failed to work together as they should have done. All the efforts of the first have been directed to the production of a powder which should carry the pressure far down the bore. This should have been met, on the part

of the gunmakers, by a corresponding increase in the thickness of the gun along the chase. It has been so met in most recent designs, but in some cases the new powder has been used in old guns; and that the number of accidents resulting from this injudicious combination has been so small, is evidence of the generally excellent quality of the guns, and the satisfactory width of the margin of safety when these guns are used with the powder and pressure for which they were designed.

As bearing directly upon the possibility of making steel of high tensile strength which shall be capable of standing a great pressure suddenly applied, the following extract from the Report of the Gun Foundry Board is pertinent:

"The latest exhibition of the wonderful character of the Whitworth steel has attracted great attention, and may be stated as indicating the present culmination of his success. From a Whitworth 9-inch gun, lately constructed for the Brazilian Government, there was fired a steel shell, which, after perforating an armor plate of eighteen inches of wrought iron, still retained considerable energy.

"The shell was but slightly distorted.

"The tests of the metal of which it was made show a tensile strength of *ninety-eight tons* per square inch and a ductility of nine per cent."

The CHAIRMAN.—*Gentlemen:*—The lateness of the hour makes it necessary to terminate the discussion, although there are several letters and papers still remaining to be read. Among the latter, the Institute would have been glad to listen to the remarks of Lieutenant Jaques, U. S. Navy, and Mr. John Coffin, Assistant Engineer of Cambria Steel Works. All these papers will, however, be printed with the proceedings of the evening.

In conclusion, I may say that it is to be regretted that Mr. Dorsey has not been present to hear what has been said upon the other side of the question; I am confident his views would have been materially modified, if he had not been entirely converted to the views which have been so ably presented in the discussion.

I venture to think that a careful comparison of opinions upon this question of hard and soft steel will reveal the fact that there is not much difference of opinion, after all. Mr. Dorsey and those who endorse his views have, I think, assumed that gunmakers are using a much harder steel than is the case.

Although the percentage of carbon in gun steel is double or treble

what is considered admissible in structural steel, yet it is evident that the increased quantity of carbon produces a quality of steel which is thoroughly reliable when properly tempered and annealed, while it possesses at the same time the immense and indispensable advantage of a high elastic limit.

Commander P. F. Harrington, U. S. N., then moved that a vote of thanks be tendered to Mr. Edward Bates Dorsey for the valuable paper contributed to the Institute, and to the gentlemen who have given us the pleasure of their presence and the benefit of their views. The motion was seconded by Professor N. M. Terry and carried unanimously. The meeting adjourned at 11.30 P. M.

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Mr. JOHN COFFIN, *Assistant Engineer of the Cambria Company, Johnstown, Pa.—Mr. Chairman and Gentlemen* :—It seems to me absurd that, from knowledge gained by a study of structural steel, with a confessed ignorance of the methods of treatment and character of gun steel, a man should attack the work done by our Ordnance Departments. The history of steel guns extends but a few years, but, short as it is, it has not been a history of failure. It seems wonderful to me that there have been so few failures in English guns. I have heard a great many stories about English practice (or malpractice) which I believe, because they come to me from reliable witnesses, but they would have no weight here.

It is a known fact that no test pieces have been taken from the tubes after treatment, but that the test pieces on which they are accepted are manufactured separately, as far as the later and most important part of the manufacturing process (the tempering) is concerned. If our ordnance officers should accept a tube in this manner and on this kind of a test, Mr. Dorsey would have some ground for his claim that they were using treacherous material. And here it might be well to understand what constitutes treacherous steel.

If we make gun material of a steel that would give 100,000 pounds ultimate and put it in the gun without testing it; or, as the English do, if we manufactured the test pieces separately, we would have "treacherous steel," as Mr. Dorsey terms it, or steel of unknown qualities; or if we worked the whole ingot up into gun steel and cut the test pieces from the bottom parts, we would have "treacherous steel," as Mr. Dorsey calls it, or dishonest steel.

In structural steel nearly the whole ingot goes into steel bars, and a steel that will weld to some extent in rolling is a safer material. In gun steel one-third of the length of the ingot is thrown away as untrustworthy, one-eighth of the remainder is thrown away from the centre of the ingot; this may be said to be a manufacturing necessity, yet it is a fact that the least dense and weakest metal is at the centre of an ingot; but for structural purposes this is all grist.

The ordnance officers of our government are not following the example of foreign governments. They are profiting by the experience of others and gaining knowledge from their failures, but I trust are not copying their mistakes. Could any pressure be brought to bear on our Congress to cause it to compel our Ordnance Departments to accept material for guns once rejected by them, and are our Ordnance Departments relax enough to allow manufacturers to hoodwink them into a system of testing which permits the considered article and the test piece which represents it to be manufactured separately? To be sure, we have only made a few steel guns in this country, and as the number increases we hope to gain in knowledge of the subject; but as far as we have gone I think it difficult to find any work in this country, or in the world, more scientifically planned or more carefully executed.

Mr. Dorsey asks some very pointed questions about oil-tempering. Surely he must know such questions must be somewhat embarrassing. There are, probably, a great many in this room who have the results in their possession of experiments carefully carried out, and in number enough to convince any one, even the most skeptical, that there was something in the process more than a name; but few of them were tried at the direct public expense, and few people can make them public without a breach of faith; yet, for the benefit of Mr. Dorsey and those who believe with him that the oil or its magic effect can only affect the surface of "so dense a material as steel," I will cite the results of a few experiments. A rolled billet 7" x 7" x 20" was tempered in oil and tests cut from one corner and from the middle. The axis of the first piece was one and a half inches from the surface, and the axis of the second piece was three and one-half inches from the surface. The result gave a difference of only 1350 pounds in elastic limit, the result of both tests being much better than the untreated material. As an illustration of the beneficial results of oil-tempering I give this experiment: A small ingot was cast seven inches square and twenty-four inches long in a cast-iron mould, poured from the top, and

no special pains taken in casting. It was oil-tempered, and a test piece cut from the bottom two inches long, 0.55 inches diameter, gave: Elastic limit, 52,000 pounds; ultimate, 88,500; elongation, 16.7 per cent.; reduction of area, 20.2 per cent. Can Mr. Dorsey or any one else show an equal test from an ingot of this size without hammering or tempering?

Now, what constitutes soft or mild steel? According to Mr. Dorsey's definition he gives the mean tensile strength at 60,000 pounds, and also says it is steel that will not harden. The Navy Department has in its possession tests from tubes of soft steel of 60,000 pounds tensile strength, a few of which I will give:

| UNTEMPERED. | | | TEMPERED. | | |
|---|---|---|---|---|---|
| Elastic limit in tons. | Ultimate strength in tons. | Elongation in inches. | Elastic limit in tons. | Ultimate strength in tons. | Elongation in inches. |
| 13 | 26.8 | .737 | 29.2 | 45.2 | .433 |
| 13 | 27.8 | .707 | 27.8 | 46 | .345 |
| 12 | 27.6 | .713 | 26 | 39.6 | .420 |
| 12 | 28 | .633 | 25.8 | 41 | .480 |
| 13.77 | 28.11 | .596 | 34.15 | 49.8 | .26 |
| 12.18 | 26.9 | .564 | 34.8 | 49.4 | .202 |

These results show beyond question that 60,000-pound steel will take temper. Furthermore, if a strong gun could be made from soft steel, which has been shown to be impossible, I believe the cost could not be reduced, as it would be more difficult to make large ingots from soft steel.

Lieutenant WM. H. JAQUES, U. S. N.—*Mr. Chairman and Gentlemen:*—The theories and opinions presented in Mr. Dorsey's paper have been so effectually refuted in the able discussions to which we have listened this evening, that there remains little or nothing to be said in relation to the technical questions therein. But there is another point of view from which it may be considered, and that is the effect which it and similar papers in the general press may have upon the general public, coming as it does from a *civil*, instead of a *military*, engineer.

At a dinner given by the New England Society in one of our large cities, an Admiral of our Navy, in reponse to the toast, "The Navy," said if the length of his speech was to be governed by the size of our Navy, he had already said too much. I do not recall, at the present moment, anything more pertinent to apply to the paper under discussion, if its application to gunmaking is alone to be considered.

When I heard that it was to be read and discussed to-night, I was opposed to its consideration, for I believed it unworthy of the prestige which publication in the proceedings of this Institute would necessarily give it. But as it has been the means of bringing together the intelligent men whom I see before me, has furnished a motive for an interesting and spirited discussion, and has given an opportunity for the presentation of the opinions of men pre-eminent in their respective professions, I must thank the writer, so far, for his success.

Though he has intimated that his argument is based upon the "experience and opinion of all the principal steelmakers of the world," his several trips to Europe and elsewhere appear to have been fruitless, for we can find nowhere in his paper any opinion that is in accord with the accepted authorities on special steels either in Europe or at home. In fact, as has been so repeatedly said this evening, he has displayed his utter ignorance of the subject he has attempted to discuss.

The arguments to which we have already had the pleasure of listening have so completely disposed of the claims and conclusions contained in his paper, that it is unnecessary for me to do more than to ask you to recall the opinions of various high authorities in the United States who have taken the interest and trouble to give important committees the benefit of their experience and knowledge. A glance at the report of the Senate Committee on Ordnance and War Ships alone will show the wide range of investigation that was conducted. It is needless for me to state that the testimony to which I refer does not accord with the views Mr. Dorsey advocates. Neither does the letter just read from Mr. Wellman. Nor in the letters expressing a preference for his "cheap material" will he be able to find much sympathy, for even Mr. Thurston, by his eulogy on Whitworth steel, at the close of his communication read to-night, completely destroys the value of his argument in the first half, and makes his endorsement of Mr. Dorsey's opinions more injurious than helpful.

What Mr. Morgan and Mr. Davenport have said this evening must convince all who have heard them, and all who will read their discussion hereafter, that our military (employing it in its comprehensive sense, with reference to both branches of the service) engineers have the hearty endorsement of all those civil and mechanical engineers who have made a careful study of the application of steel to ordnance purposes. I will not quote, therefore, from the powerful evidence which they have from time to time given on this question.

Notwithstanding all this positive testimony from the leading managing and mechanical engineers of the country, the advocates of "cast iron" and "mild steel" for ordnance materials claim, in speaking of the failures of guns in Europe: "This is what might have been expected. Every steelmaker who is not a gunmaker says these large masses cannot be forged so as to be safe from injurious strains. Every mechanical engineer who is worthy of the name knows that such masses of rings and tubes cannot be fitted and assembled so as to act as a continuous whole; and even if they were so fitted, they could not be retained in that condition after the warming up of the first few rounds."

Does the evidence to which we have referred endorse either of these unwarranted statements? Are they proved by the splendid treatment that Whitworth and Schneider give their metal, and by the interesting experiment made by Sir Joseph Whitworth to illustrate the effective power of shrinkage?

[*From Proceedings Naval Institute*, No 31.]

"Plate XXXVI. presents the result of a most important and interesting experiment made by Sir Joseph Whitworth to illustrate the effective power of shrinkage. The ring was made of mild, fluid-pressed steel, and was heated and shrunk on to a plug 18 inches in diameter. When cold, the plug was forced out by an hydraulic pressure of 3200 tons.

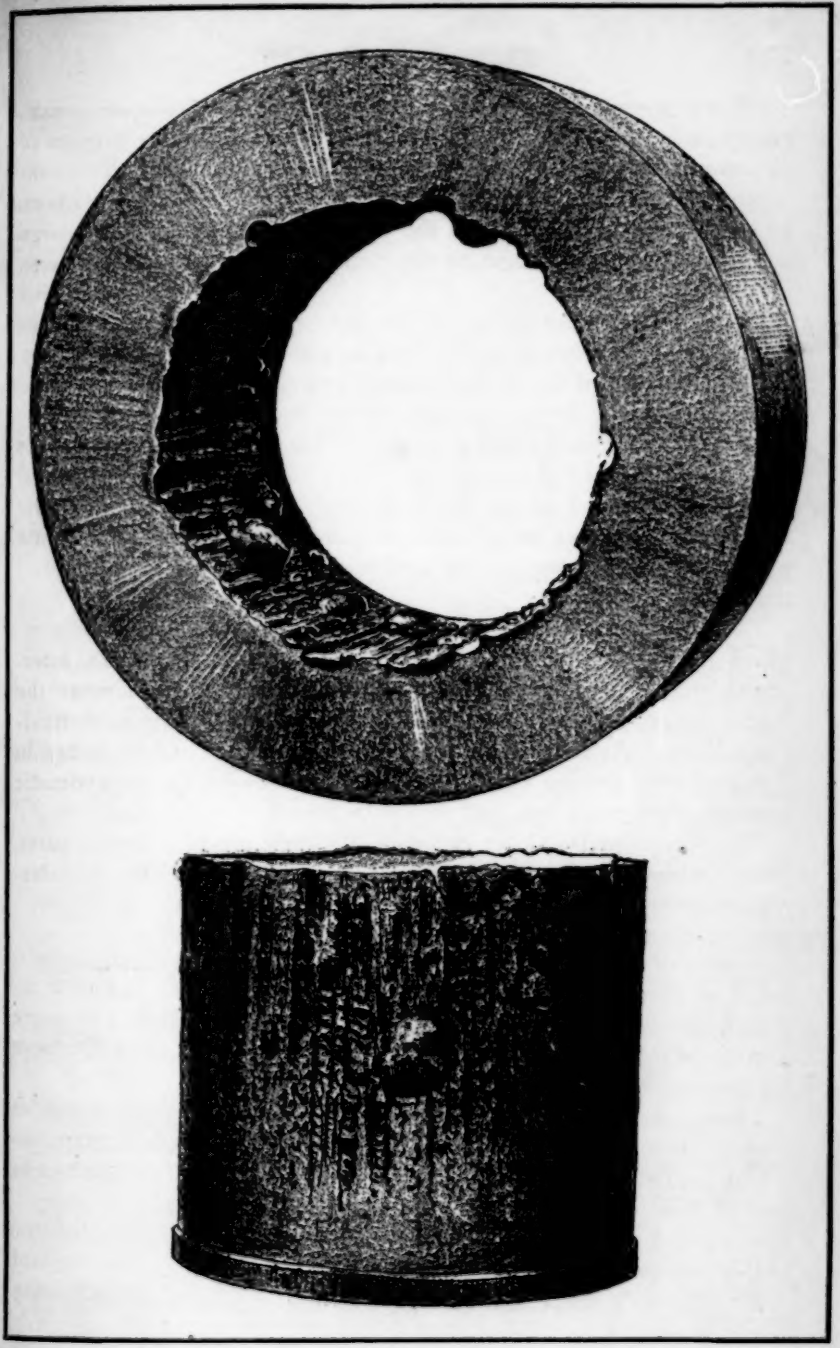
"The experiment thoroughly proved the union of the two parts, and is an excellent test of the merits of shrinkage without the interposition of any other metal."

Far from it! On the contrary, they are the evidences and practical results which aided the Gun Foundry and Fortifications Boards to make their valuable reports, and the Senate Committee on Ordnance and War Ships, in General Hawley's positive and comprehensive report, to present the following conclusions:

"All the guns in our Army and Navy, save the modern steel rifles ordered for the monitors and cruisers, are of classes whose manufacture is abandoned by the nations which have devoted themselves to perfecting cannon.

"The argument based upon the alleged economy of the cast-iron heavy rifle has been steadily losing force by reason of the constant cheapening of the processes of making gun steel, and the increasing ease of forging it in large masses.

PLATE XXXVI.



SIR JOSEPH WHITWORTH'S EXPERIMENT SHOWING
THE EFFECT OF SHRINKAGE.

"When a comparison is made between two guns giving an equal energy, it is found that the steel gun weighs but little more than half its competitor, and costs but little more. Such are the manifest uncertainties and weaknesses of the cast-iron gun, that the argument may be considered closed. This is the emphatic judgment of Europe, and in accepting that judgment this committee concurs with our own officers and experts.

"In every detail the advance of the last twenty-five years has been wonderful. The adoption of slow-burning powders, producing greater force with reduced strain, necessitated longer guns, whose use was made possible by breech-loading mechanism, bringing with it an increased rapidity and safety of loading. The attempts to make long rifles of cast iron, or of iron and steel, have been abandoned (and the value of wire-wound guns is still a question), since open-hearth steel and hydraulic forges have made comparatively easy the forging of 75-ton ingots of homogeneous steel exhibiting the highest qualities required for guns.

"The costly experiments of twenty-five years have reached a stage which justifies certain conclusions. Guns should be made of open-hearth steel, forged, breech-loading, chambered, of calibres ranging from five to sixteen inches, of lengths ranging from thirty to thirty-five calibres. Armor and projectiles should be made of forged steel. The hydraulic forging press produces better results than the steam hammer, costs much less, and should be used for Government work."

The objections that have so frequently been given by those individuals whose systems have been rejected—viz.: that military boards always exclude the ideas and inventions of the civilian that their own may be introduced and adopted—can have no pertinency in the consideration of the conclusions of the reports from which I have quoted, based as they were upon such a wide civil investigation; while the Fortifications Board, as you all know, had the benefit of the valuable services of the representative from Cambria, who has honored us with his presence to-night.

I have asked your consideration of these facts to emphasize the assertion that any attention paid to the wild theories of the iconoclasts, whose limited research and want of experience preclude a consciousness of their own ignorance, is not only an injustice to scientific students and practical men, but an impediment to the inauguration of that defense in which the whole country now believes.

Mr. Dorsey's skepticism in regard to the improvement of large

masses of gun steel by oil-treatment is endorsed by men of authority, and even so late as October last, by so prominent a one as the newly elected President of the British Iron and Steel Institute, Mr. Daniel Adamson, who, at the autumn meeting, expressed his want of confidence in "hardening in oil," even to "recommending the Government at once to consider, and to abandon it, if they came to the same conclusion that he had done—that the method was injurious at all times, and never desirable." He thus disputed the firm ground held by Professor Akerman, that "hardening in oil was a very important method for strengthening guns."

Mr. Vickers gave evidence that his experience of fifteen years was very much in favor of treating steel with oil; and a visit to his works in Sheffield would convince you all, not only of its utility, but that Mr. Vickers had many practical reasons for his endorsement of oil-treatment.

As early as 1863 we find prominence given to strengthening by oil-treatment. In the statement of Mr. Whitworth before the English Ordnance Committee, in advocating *built-up steel* guns, we find: "I go with Krupp, of Essen, the manufacturer of homogeneous metal. It is highly desirable it should be of right temper and properly manipulated." Since then its importance has greatly increased, and its use become more general. In fact, no gunmaker would be willing to take the responsibility of omitting it. In addition to gun, armor and projectile steel, shafts, hydraulic cylinders, rolls, rods, and other parts of machinery have been improved by oil-treatment, and the variety of its application is constantly increasing.

While the very general practice of oil-treatment has not reached a point where its results can be called *conclusive*, they are sufficiently definite to govern the most reliable manufacturers in their treatment of steel, and to enable them to produce very satisfactory results in large pieces.

It will be of interest to refer to a statement made last year by a member of the British Iron and Steel Institute, which was a public expression of the opinions held by many Englishmen: "During the last year or two some of our most prominent artillerists have been advocating the use of milder steel, both for the barrels and hoops of guns, than has previously been thought desirable, or than is necessary to pass the Government tests; and many of the guns now made for foreign governments are of a material the elastic limit of which is twenty-five tons, ultimate strength 33.9 tons per square inch, and

elongation twenty-nine per cent. in a length of two inches, when tempered at 1600° F. The subject of tempering and annealing is one which has not yet received, even at the hands of steelmakers, the attention of which I believe it to be worthy, and its methods of manufacture and working are therefore not so thoroughly understood as those of the softer steels, which are sent into the market in the form of boiler and ship plates, angles, bars, tees, girders, and other sections; and although any decided increase in the hardness of these things would, no doubt, lead to many serious difficulties, several eminent engineers have, during the last year or two, advocated the employment of steels of greater tensile strength for bridgebuilding and some other purposes than have hitherto been thought advisable. I think that most people will be ready to admit that the quality of the materials supplied for the construction of our weapons of war should be the highest possible, almost even regardless of cost, when so much may depend upon the safety and endurance of our guns, or on the power of their projectiles to penetrate the armor-clad forts or ships of an enemy."

If it be true that fair results can be obtained with "mild steel," though badly worked, this should be a powerful reason why it should be avoided, not only for heavy guns, but for every other purpose where certainty and reliability and strength are required. A pertinent remark in regard to this will be found in the *Army and Navy Register* of June 26 last, where, in an article on "Modern Artillery," reasons were given to account for the failures of English material. "The difficulty lies," says the writer, "in the fact that English manufacturers furnish the cheapest steel in the world; and in order to make cheap steel into guns it is necessary to lower the Government requirements of physical characteristics, temper, etc., to a point where no reliable gun can be made. The very best material must be used in the composition of the steel, or it will not stand the work that it is necessary to put into it to make it homogeneous; that material and that work must be paid for."

Is it, then, of such material as Mr. Dorsey advocates that military engineers should construct guns to sacrifice their country and their fellows? Is it to such material that military engineers are to yield, just as they have succeeded in securing a production from steel manufacturers who (after enormous expenditure) have reached a point where they can guarantee the uniformity and homogeneity, as well as the other requisites, of reliable gun metal?

Is it with such material that we are to invite similar failures (they will certainly come if we use the stuff he advocates) to those he condemns in England? I am sure no ordnance officer in either of our departments would think of advocating such a policy, and no one would dare do it, if he were required to stand by and fire his own guns.

An eminent artillerist said to me last summer, in Europe, that he had made unforged gun metal that, *theoretically*, was as strong as any forged steel he knew, and that he believed he could make a safe gun of it; but he did not believe it capable of such high ballistic power as forged steel ordnance was capable of obtaining; and, further, if he were Director-General of Artillery, he would consider it a criminal act on his part if he gave orders for its production and issue to the service.

I would like to add here that the vigorous attacks made during the past year in England have been upon the system of supply, poor material, bad design, individuals, conservatism, and absence of suitable, intelligent experiment. But nowhere in this prolific literature can there be found any demand for poorer, cheaper material to replace the characteristics that for so long have been too low instead of too high. On the contrary, one of the accusations of the English press called attention to the low characteristics, intimating that they were laid down for the special benefit of one firm, to be altered from time to time as that firm's production improved.

I do not agree entirely with the writer of the article on "Modern Artillery," from which I have quoted the above passage. As far as Sir Joseph Whitworth & Co. are concerned, it must be remembered that it is only within a limited period that this firm has received any orders for finished guns, and there is nowhere on record the bursting of any British gun manufactured of their material. In regard to design, I have some information which justifies me in saying that this firm's protest against the insertion of the liners in two parts in the guns under manufacture by them for the British Government caused the War Office to alter their designs in this important feature, at least as far as the contract with Sir Joseph Whitworth & Co. was concerned.

The steel we want for guns cannot be described by either of the terms "mild" or "hard" which Mr. Dorsey has employed. It must be *tough* and *elastic*, and manufactured with the greatest intelligence and care, from the selection of the charge to the finishing of the gun.

There must be nothing "*cheap*" about it, no uncertain or inadequate treatment. Such steel as we want exists abroad, and is fabricated into guns that have not and will not burst before a long life has been reached. It has already been made in small quantities in this country, and, as the demand increases, will soon be manufactured in larger masses.

In regard to the material of which the guns that have burst in England were made, it must not be forgotten that of the material in the Collingwood gun, the committee said there was a want of uniformity and proper treatment. My inquiries of the Chairman of Krupp's administration brought forth an absolute denial of the statement of Colonel Hennebert relating to the disabling of German guns at the siege of Paris, afterwards quoted by the Duke of Cambridge. But even admitting that thirty-six German guns were disabled, the result of the struggle between the two powers was sufficiently definite to point out what splendid work the remaining ones accomplished.

The failures to which Mr. Dorsey has referred prove that *poor* steel of any physical characteristics is no more fit for guns than was the inferior steel for their purposes that the civil engineers used for structures, and which reflected so seriously, but falsely, upon the use of steel as a superior material to iron. I claim that the failures of the steel guns in England (I suppose them to be the ones to which Mr. Dorsey refers) resulted from causes entirely distinct from those that he imagines them to be. By no journal has this matter been more thoroughly and ably handled than by the London *Engineering*. This paper, edited by men of high technical ability, is an advocate of the opinions and work of a large number of British mechanicians. As you all know, and have probably read, there have appeared exhaustive reviews of the sad condition of England's gun supply. Severe as these attacks have been upon administration and methods, all the articles have demanded more powerful ordnance and better material.

I believe that Captain Michaelis, of the Ordnance Corps of the Army, is the only military engineer who quotes the essayist to any great extent; while in the Navy there also remains one isolated example, who has stated that he is "firmly convinced that the gun of the future, both for seacoast and afloat, will be a *steel-cast gun*." Against the opinions of such names as Dorsey, Michaelis, Metcalf, Thurston, Howe, Evans, William P. Hunt, Haskell and Wiard (who advocate cheap material of one kind or another), I feel myself on very

solid ground in accepting the work of Whitworth, Schneider, Krupp, Vavasseur, Kolokoltzoff, Simpson, Fritz, Leavitt, Joseph Morgan, Jr., Davenport, and Birnie, and hope I may be allowed the benefits of their advice and guidance for many years yet to come. If the former are content to remain where Rodman brought the ordnance problems, the latter are not; and I am confident, were General Rodman alive to-day, he would be as firm an advocate of forged, oil-treated steel of high physical characteristics as either Krupp, or Whitworth, or Schneider. I look upon the persistent attempts to keep gun construction where Rodman left it, which have had so much influence in blocking progress in the Army, as a reproach to his memory and to his attainments.

Sometimes the minority is right, but there appears to be no chance for it in this case; for if forged steel built-up guns are not the best, there has been ample time since 1843 to discover the mistake. Instead, however, of there being a shadow of a doubt as to their superiority, every power on the face of the fighting earth has accepted a steel of the characteristics Mr. Dorsey condemns. Mr. Hewitt's answer to an advocate of cast-iron ordnance—"Of course you are aware that you have the judgment of every military engineer against you"—applies well to the essayist's theories; and, further, not only is the judgment of every military engineer against them, but there is added thereto the weighty judgment of the most eminent steel manufacturers of the land, the majority of whom, I am informed, have not only not been consulted by the essayist, but have never even heard of him.

Before closing I desire to call the attention of all the members of the Institute to the pleasure I have had, during my recent visits to Europe, to hear on every side such honorable mention of the work this Institute has done, and the esteem with which our worthy President, Admiral Simpson, is held by the military scientists of the Old World as well as the New.

These facts, added to the honor and merit that have been conferred in complimentary notices by the foreign press, should be most gratifying incentives for its further development.

Professor CHAS. E. GREENE, *University of Michigan, Ann Arbor, Michigan.*

Material, to successfully withstand great shocks repeated a number of times, ought to have a large capacity for absorbing energy. This

capacity will be measured by the product of two quantities—deformation, and the mean resistance overcome in producing the deformation. The best material, therefore, will be, not that which has the highest ultimate or breaking strength, nor that which has the greatest ductility or deformation under a given stress, but that material or grade for which the product of these factors is a maximum.

A careful reading of published results of experiments on different grades of steel and of actual work leads one to conclude that high steel, while possessing great tensile strength, is deficient in ductility, or is brittle. Toughness is what is wanted. It also appears that the requirements of the Ordnance Office of the War Department that the steel for hoops for 8-inch guns shall have a tensile strength of not less than 100,000 pounds per square inch, with an elongation after rupture of not less than twelve per cent. in six inches, embody two limits which are likely to be incompatible; that is, 100,000 pound steel will not have that amount of stretch, and steel of that ductility will have a less tensile strength.

The points which Mr. Dorsey has emphasized in his paper are well taken, and I agree with him in his opinion of hard and mild steel.

FRANCIS COLLINGWOOD, C. E., *Assistant Engineer during Construction of New York and Brooklyn Bridge.*

Your communication, with request for discussion of Mr. Dorsey's paper, reached me in due time. I have delayed replying in hopes that I might find time to write briefly my views, but am altogether too busy just at present to do so. I do not think, however, that I could add anything to what I have said already in a discussion on Mr. Schneider's paper on the Niagara Cantilever Bridge, which you will find on page 577, etc., of the *Transactions of the American Society of Civil Engineers* for 1885.

My attention has been turned chiefly to the proper material for bridges and similar structures, such as will test in unworked specimens at about 70,000 pounds, or when drawn into wire of one-eighth inch diameter at about 150,000 pounds. The great difficulty of securing uniformity of state in large masses, when higher grades are used, resulting in unknown internal strains which cannot be guarded against, is a strong argument against their use. In these days of improvement and the rapid advances that are making in all metallurgical operations, it will not do to say that such difficulties will not

disappear. I am inclined to think, however, that they still exist at the present.

The discussion I mention summarizes the methods of tests and requirements extant abroad at the time of a visit made there in 1884.

HIRAM S. MAXIM, C. E., *The Maxim Gun Company, London, Eng.*

Highly carbureted steel, or hard steel, is unquestionably more apt to break and much more unreliable than soft steel, especially in large pieces. Any one who has worked this kind of steel knows that every cut taken from it changes its shape. If a large piece be placed on a planer and a heavy cut be taken from one side, the piece warps; in fact, every time a cut is taken from any portion of it the whole mass seems to warp and twist. This is due to the fact that there is not a state of molecular rest in the mass.

If a large block of this hard steel should be cut into a number of strips, it would be found that no two of them, after cutting apart, would be exactly the same length: some would be longer and others shorter than the block from which they were cut.

I do not regard tempering in oil, as conducted in England, to be beneficial to the tubes of large guns.

The experts who constituted the committee of inquiry in the Collingwood gun have given for a reason that the tube burst because it was not annealed after it was tempered. The annealing, to my mind, would place the tube in exactly the same condition that it was before it was tempered at all; in other words, the effect of tempering would be completely removed by annealing. If a large forging of steel be cooled from the outside, the outside becomes hard and incompressible while the inside is still very hot. Now, when the inside comes to cool, it shrinks, and as it cannot shrink away from the outside, it is put in a high state of tension; while the outside by being drawn inward, is put in a high state of circumferential compression. If the steel be of hard quality, cracks may form in the interior. At the instant these cracks form a loud click is heard, so that faults of this kind are technically called "clicks" at the steel-works. They may be either longitudinal or transverse clicks.

All British guns are made of steel which is sufficiently carbureted to be susceptible of being tempered; the fact is, this steel may be made quite hard if tempered like ordinary steel. I myself have made very fair drills of it. The tube of the Collingwood gun was tempered

from the outside, and of course, the outside becoming cooled before the inside, the outside was put in a state of compression, the exact reverse from what it should have been to stand internal pressure.

Before firing, the outside of this gun was attempting to pull the inside asunder, and only required the assistance of a moderate internal pressure to start the crack. If the tube had been cooled from the inside, the exact reverse would have been the case, the inside being in a state of compression and the outside in a state of tension. The first would have been improved by annealing, and the latter injured for the purposes of a gun.

With a low grade of steel, however, these differences in tension are not set up in the same degree; to be sure, the steel is much weaker, but all its particles pull in the same direction. It is not a house divided against itself.

I have lately had quite a controversy with some gun experts. I have taken the ground that the guns burst because they were cooled from the outside instead of from the inside. I made numerous diagrams to show the molecular strains set up in steel when tempered from the outside and when tempered from the inside, and have tried to point out that tempering from the outside was worse than no tempering at all.

I was at first strongly combated, but by persistence, and by making the matter very plain, I in the end succeeded in convincing them all that I was right.

In conclusion, I would say, if in the use of hard and strong steel it is not possible to make all of the particles pull together, then by all means make guns of soft steel.

ROBERT W. HUNT, *General Superintendent Troy Steel and Iron Company.*

*Gentlemen of the Institute:*—In response to your invitation to discuss Mr. Dorsey's paper on "Steel for Heavy Guns," I will offer but a few brief remarks, based on my experience as a maker and user of steel.

It is hardly necessary for me to state that I have not had experience in making steel for heavy guns, and that my knowledge of its behavior in such form is based entirely upon report. But I have encountered, and often in disagreeable professional ways, the treacherous, or perhaps it would be better to call it unlooked-for, behavior

of high steels in parts of machinery. As stated by Mr. Dorsey, every establishment in which large pieces of high steel have been used has its story of many unexpected failures. That such failures should occur is easily understood and fully explained by the well-established fact that the change of volume due to heat increases with the quantity of carbon in the steel, which must of course make metal with a high percentage of that element more liable to internal strains than a low-carbon steel. As the carbon increases, so does the danger. To guard against this, all depends upon the care exercised in the forging and annealing. Should any one fail in this care, or the use of proper judgment, the disastrous result in the case of a gun would only be known after much money had been expended, and when its loss would be the smallest part of the calamity.

Soft steels are made by many well-established firms, and with as great uniformity as belongs to any large manufacture. Of course, for so particular a purpose as the manufacture of ordnance, the *best stock* would have to be used and the greatest skill exercised in making the steel; but the risk of failure would approach zero, as compared to high steels, and such heats or charges that should fail to stand the required physical tests could be applied to ordinary commercial purposes without loss to the maker, and for which the metal would be well adapted. Then, after the steel was made, the risk of ruining it in subsequent manipulations would also be reduced to the minimum.

If I mistake not, the experience of the United States Ordnance Corps has demonstrated that soft steel is the proper metal for the construction of field-gun carriages. And you will permit me to give the physical test of the steel from which the successful carriage was constructed. The specimen was twenty inches long, two and a half inches wide at shoulders, seven and a half inches between shoulders, and 0.254 inches thick. Upon the Watertown testing machine it gave per square inch 70,990 pounds tensile strength; 27.4 per cent. elongation; 52,460 pounds elastic limit, and 44.8 per cent. contraction of area. Its carbon was 0.17 per cent., and it broke with a silky fracture. It seems to me that such metal would be the grade to use in the construction of heavy guns, if they are to be made from forged pieces. But why should the authorities so persistently decline to investigate the merits of *cast-steel* guns? The investigation would cost but little, and I am sustained by the opinion of many able steel-makers in believing in that form of manufacture we will find the

cheapest and best guns. There are American works ready now to make the trial, and if successful, the requirements of the country can be rapidly met, and without asking any one to risk some millions of dollars in the construction and capitalization of a plant which may prove a failure. We have plants capable of casting the gun or guns, and the Government has at South Boston tools *now ready* to finish them. Fifty thousand dollars would afford an ample fund.

Mr. T. F. ROWLAND, *Proprietor Continental Works, Greenpoint, N. Y.*

Under date of December 9, 1886, I had the honor to receive from the Institute a copy of a paper by Edward Bates Dorsey, C. E., entitled "Steel for Heavy Guns," which paper will be read at a meeting of the Institute on the 5th inst., upon which occasion, as it is impracticable for me to be present, I am invited to express my opinion and criticism of the paper in writing. In response to said request, I have carefully read Mr. Dorsey's paper, and I beg to say I heartily agree with the statements and conclusions therein contained.

Having been more or less engaged for the last fifteen years in the working of Siemens-Martin and Bessemer steel plates, welding the same into various forms, such as cylinders for boilers, cylindrical vessels to contain excessive pressures, notably liquid carbonic-acid receivers, torpedo cases, etc., I long ago discovered that steel much exceeding sixty-five thousand pounds (65,000) T. S. was treacherous and unreliable to the last degree, whereas steel of not more than sixty-three thousand pounds (63,000), or less than fifty-five thousand pounds (55,000), preferably the average, could be wrought and welded into any shape with full assurance as to the results.

In 1880 I took an order to furnish a number of welded-steel receivers, which were to be sent to Russia to be incorporated in the "Lay Patent Torpedoes" then being built for that Government. These receivers were intended to contain the liquid carbonic acid used to produce the torpedo motive power. The method of construction was the rolling and welding into cylindrical forms, twenty-four inches in diameter and four feet long, sheets of Siemens-Martin steel half inch thick, into the ends of which suitable steel heads were welded. The tensile strength of the steel of two of these cylinders, as stated by the Naylor Steel Works, of Boston, who manufactured the plates, was ninety thousand pounds (90,000); the other plates were stated as of sixty thousand pounds (60,000).

The receivers made of the 90,000-pound metal burst under hydrostatic pressure of fifteen hundred pounds (1500) per square inch, which was equal to thirty-six thousand pounds (36,000) strain per square inch of metal. Pieces of the steel broke out as if the receiver had been made of cast iron. The receivers made of the sixty thousand pounds T. S. (60,000) metal were tested to seventeen hundred pounds (1700) per square inch (hydrostatically), or to a tensile strain of forty thousand eight hundred pounds (40,800) per square inch of metal, and withstood it without any damage to the material. Since then I have made it a rule to purchase no steel of over sixty-five thousand pounds (65,000) T. S.

I have lately manufactured one hundred and fifty (150) welded-steel (55,000 pounds T. S.) cylinders six feet four inches diameter, thirty inches long, quarter inch thick, with two-inch external flange turned upon each end, which flange I have turned cold in a machine provided for the purpose, a feat which would have been impossible of accomplishment had the metal possessed a high degree of tensile strength.

I fully agree with Mr. Dorsey in his statement that steel of a given tensile strength varies in reliability and value as its thickness, the maximum approaching where the metal is thinnest; and I believe that what he designates as "*mild*" is a more suitable metal for the construction of guns than the quality he designates as "*hard*."

True, the latter has a greater theoretical value, but it cannot be depended upon, while the former can be.

In the manufacture of guns, it would seem that a number of thin hoops or cylinders constructed of metal whose value is known and is reliable, would be much preferable to one hoop or cylinder equal in thickness to all the others, and whose value, though theoretically known, is, in practice, utterly unreliable.

In conclusion, I beg to reiterate that my convictions upon the matter in question are in full accord with the statements made in Mr. Dorsey's paper. It is a valuable document, and he well deserves the thanks of all workers in steel for having brought the question before the Institute, where it will doubtless receive proper discussion.

Very respectfully, THOS. F. ROWLAND.

C. C. SCHNEIDER, C. E., *New York.*

The experience of bridge engineers confirms Mr. Dorsey's opinion that steel having an ultimate strength of over 100,000 pounds per

square inch is unreliable and unfit for structural purposes. The treacherous qualities of hard steel, owing to its crystalline nature, are well known to all workers in that metal. If used for parts of structures not exposed to external injuries, mild steel of from 60,000 to 70,000 pounds ultimate strength, which has been carefully worked, I consider just as reliable as the best wrought iron, besides having the advantage of greater strength. If it were possible to combine the fibrous nature of wrought iron with the high ultimate strength of steel, we would have the most suitable and reliable material for structural purposes; and, in my opinion, this would also make an excellent material for heavy guns. The nearest approach to this is wire rope made of good steel.

For the sake of economy, I deem it advisable for our Government, before spending many millions of dollars on new guns, whose efficiency in actual service is doubtful, to have this subject thoroughly investigated by a series of careful experiments conducted under the supervision of able and experienced men.

Mr. JAMES CHRISTIE, C. E., *Philadelphia, Pa.*:—I am not sufficiently acquainted with the reasons that have influenced the choice of the grade of steel specified to hastily condemn the action. Not only high tension, but also the power to resist erosion must be considered, and no doubt the latter power is increased by tempering the finished material.

I agree with Mr. Dorsey, and think that common experience will justify his assertion that for purposes where severe shock or suddenly applied or accelerated strains are applied, hard steel is not an entirely trustworthy material; and more especially is this true when rapid changes of temperature are involved.

But while this "capricious" property, as it is termed by Mr. Dorsey, is more apparent in the hard steel, I cannot agree with him that it is entirely absent in the extremely mild and ductile steels.

Steel of any grade is affected to a marked extent, as compared with the best wrought iron, by disturbance of its surface, in this respect bearing some analogy to the behavior of glass when scratched by the diamond.

I have repeatedly seen steel cracked by the drop test with a facility that, under similar circumstances, would have ensured the condemnation of wrought iron, and from no greater cause than a scratch skin-deep around the body. I acknowledge that this weakness is more

evident in the high-tension steels, but it is also found in steel of the lowest tension and highest ductility, and in metal which previous to being scratched seemed capable of enduring an astonishing amount of torture. Steel is peculiarly liable to surface abrasion if both rubbing surfaces are soft and not thoroughly protected by some lubricant. The tempering process affords great relief from this tendency to abrasion, and no doubt in the case of steel guns would give increased resistance to the destructive effect of interior erosion.

In the case of mild steel that will not take any perceptible temper by cooling from red heat, it has been found a marked advantage, in resisting abrasion, to case-harden the surface by the methods usually practised with iron.

A marked improvement in the strength and endurance of steel has been abundantly proved by compacting the metal by the forging process. In the absence of any experience on the subject of steel for ordnance, I would be led to believe, on general principles, that the best results would be attained by the use of the most ductile metal, even if its tensile strength were the minimum, for the body or strength-giving part of the gun. The chamber might be case-hardened on its interior surface, or, if this should prove impracticable, a harder steel, oil-tempered, might be used. The whole subject is worthy of the careful consideration of the authorities before committing themselves to the use of any particular grade of steel.

PENNSYLVANIA RAILROAD CO.: MOTIVE POWER DEP'T.
ALTOONA, PA., *December* 27, 1886.

EDWARD BATES DORSEY, Esq.

*Dear Sir:*—Referring to yours of December 21st, in regard to steel for heavy guns, I have read over your paper with very much interest, and may say that in general I agree entirely with the conclusions which you have reached. In my judgment, no more serious error has been made in later years by engineers everywhere than the attempt to use steel of 80,000, 90,000 or 100,000 pounds tensile strength in constructions.

We have had considerable experience on the Pennsylvania Railroad with such steels, and have uniformly found them unsatisfactory.

If possible, I shall be at the discussion on January 5. I am a little afraid, however, that I may not succeed, and lest I should not be there, I will say that although I might not agree to everything said in

your paper, I fully agree with the main conclusion—that it would be best to use mild steel for heavy guns.

Very truly yours,

CHAS. B. DUDLEY, *Chemist.*

WASHINGTON, D. C., *January* 4, 1887.

SECRETARY U. S. NAVAL INSTITUTE, *Annapolis, Md.*

*Dear Sir* :—In the matter of the use of high-grade steel for guns and other structures subject to variable strains, I have been obliged to make considerable study as Chairman of the Committee on Military Affairs of the 48th Congress, which committee was compelled to go into some investigation, and has made a report with the testimony taken, which has been printed.

I regret that I cannot forward a copy of the same to the Naval Institute; but the outcome of all I know in the matter is thoroughly confirmatory of the views taken by E. B. Dorsey in his paper, copies of which I have had to thank you for.

Had I time, I would formulate my conclusions on the subject, with reasons therefor. Failing that, I desire to state, as above, my conclusions.

Very truly yours,

W. S. ROSECRANS.

CRESCENT STEEL WORKS: MILLER, METCALF & PARKER.

PITTSBURGH, *December* 9, 1886.

EDWARD BATES DORSEY, Esq.,

*127 East 23d St., New York.*

*Dear Sir* :—I object decidedly to your statement that the cracking and breaking of high steel is "mysterious and unaccountable."

There is no mystery about it. High steel is a truly crystalline substance, like glass, and obeying the same laws.

Langley showed, years ago, that high steel increased in volume per degree of temperature very much more than mild steel, by taking the specific gravities of different grades of steel under the same conditions of treatment. See chapter "Why Does Steel Harden?" in "Treatment of Steel." This increase of bulk, when not perfectly uniform in the mass, sets up injurious internal strains in high steel, sometimes breaking the piece in manipulation, sometimes leaving it in a state of unstable equilibrium for subsequent failure. That is all there is of the mystery.

It is certain that high steel cannot be forged in large masses, nor pressed, nor worked in any way so as to be practically safe.

Oil-tempering strengthens all steel; so does water-tempering; so does quick cooling in any manner. It is always a dangerous operation, the danger increasing with the size in geometrical progression, and with the hardness of the steel the danger ratio is much greater. Wade and Rodman proved, many years ago, that quick cooling increased the strength of cast iron, but neither of them ever tried to make a chilled cast-iron gun. Engineers are all looking in the wrong direction in studying steel; they are studying modes of cooling, forging, tempering, etc., when in fact the properties are all given and varied by heat.

The heat in melting, the heat in pouring, the rate of cooling, and the heat at which to anneal—these are the controlling manipulations, and they are also the easiest to control.

Your thin-hoop guns and the wire guns lead out to the true theory —that is, to have an infinite number of hoops or wires acting radially, tangentially, and along the axis. These can be obtained by casting, cooling and annealing.

The annealing can be repeated as often as necessary, the cooling can be controlled in the desired direction, and the whole operation would be sure, safe and cheap. Yours very truly,

WM. METCALF.

THEO. N. ELY, *General Superintendent of Motive Power Pennsylvania Railroad Company*:—Probably I cannot add much of value to what has already been written and said, but wish to express myself as in entire sympathy with the general conclusions reached by Mr. Dorsey in the paper which you forwarded, agreeing as they do so well with the experience which we have had during the last twenty-five years in the use of steel for boilers and fire boxes, as well as that used for car axles and a number of the parts of locomotives, such as tires, crank pins, etc.

The enclosed printed specifications will indicate more clearly what the practice of the Pennsylvania Railroad Company is in the purchase of steel.

Some years since, in order to strengthen some iron bridges the design of which did not admit of tension rods of larger diameter, steel was substituted for the iron rods; but the results were not satisfactory, as the steel was too high, and in the endeavor of the nuts to adapt themselves to the surfaces against which they were pressed, fracture at the thread was soon developed.

That part of Mr. Dorsey's paper which refers to the danger of ruptures occurring in steel, induced by dints or abrasion, is worthy of careful consideration.

Recognizing the dangers of a final rupture, due to incipient cracks or imperfections, it has been the custom of this company for some years to have the steel axles used under passenger-equipment cars rough-turned throughout their length; the higher the steel, the more liable it is to crack.

This property of steel we speak of as "breaking in detail"; this is very well illustrated by a piece cut from the journal of an axle which broke in this manner.

I have never known steel axles to break in any other way. The starting of this fracture is possibly due to the journal having been cut by some foreign substance.

In conclusion, I would say that when steel is used we endeavor to keep it as mild as possible, in many cases increasing the size to obtain the stiffness necessary, rather than to use steel of higher grade. Of course we are sometimes limited in this respect, and have to use a little higher steel than we consider the proper grade.

This letter has been hastily composed, but you are at liberty to use it in any way you may deem proper.

## SPECIFICATIONS FOR CRANK PINS.

**All specifications for crank-pin steel heretofore issued are hereby annulled and superseded by the following:**

**Steel ingots for crank pins must be swaged as per drawings.**

**For each lot of fifty ingots ordered, fifty-one must be furnished, from which one will be taken at random, and two (2) pieces, with test sections five-eighths inch diameter and two inches long, will be cut from any part of it, provided that centre line of test pieces falls one and one-half inches from centre line of ingot. Such test pieces should have a tensile strength of 85,000 pounds per square inch, and an elongation of fifteen per cent. Ingots will not be accepted if the tensile strength is less than 80,000 pounds, nor if the elongation is below twelve per cent.***

## SPECIFICATIONS FOR STEEL BILLETS FOR MAIN AND PARALLEL RODS.

**One billet from each lot of twenty-five billets or smaller shipments of steel for main or parallel rods for locomotives will have a piece drawn from it under the hammer, and a test section will be turned down on this piece to five-eighths inch in diameter and two inches long. Such test piece should show a tensile strength of 85,000 pounds and an elongation of fifteen per cent.**

*** Stiffness desired. Size cannot be increased.**

No lot will be acceptable if the test shows less than 80,000 pounds tensile strength, or twelve per cent. elongation in two inches.*

## SPECIFICATIONS FOR PLATE AND SHEET IRON AND STEEL.

All iron and steel plate other than boiler, fire-box and tank-steel plate, and all sheet iron and steel, whether black, galvanized or planished, will be designated on orders as "No. 1," "No. 2" or "No. 3," to show what quality is wanted, and materials furnished on such orders must be of such quality as will meet the requirements of the following specifications for the material ordered, which will supersede the specifications for sheet iron dated March 2, 1883.

### No. 1.—Plate and Sheet Iron and Steel.

No. 1 plate and sheet iron and steel must be of a grade that is suitable for flanging and edging with and across fibre, such as plate for track tanks and tank heads; sheet, black or galvanized, for the most difficult parts of head-lights, canopies, linings, casings, ventilators, hoods, buckets, elbows, spouting and passenger-car roofs; planished sheet for boiler-jacket collars.

No. 1 plate one-eighth inch thick or over must have a tensile strength of not less than 48,000 pounds nor more than 60,000 pounds, and an elongation of twenty per cent. in section two inches long, and the thinner forms of sheet metal must stand the working as prescribed above without cracking.

### No. 2.—Plate and Sheet Iron and Steel.

No. 2 plate and sheet iron and steel must be of a grade that is suitable for flanging when the line of the flange runs across the fibre, such as black or galvanized sheet for freight-car roofs, locomotive smoke stacks and wheel covers; planished sheet for the main portion of boiler jackets.

No. 2 plate one-eighth inch thick or over must have a tensile strength of not less than 45,000 pounds nor more than 55,000 pounds, and an elongation of fifteen per cent. in section two inches long, and the thinner forms of sheet metal must stand the working as prescribed above without cracking.

### No. 3.—Plate and Sheet Iron and Steel.

No. 3 plate and sheet iron and steel must be of a grade suitable for rolling and riveting, and must stand punching for use in flat sheets and rolling into cylindrical form, such as smoke jacks and plain cylindrical casings.

No. 3 plate one-eighth inch thick or over must have a tensile strength of not less than 42,000 pounds nor more than 55,000 pounds, and an elongation of ten per cent. in section two inches long.

## SPECIFICATIONS FOR AXLES.

Car axles and locomotive-tender and truck axles will be ordered subject to the following conditions, which annul all previous requirements:

For each 100 axles ordered, 101 must be furnished, from which one will be taken at random, and subjected to tests prescribed for such axles. If the axle stands the prescribed test, the 100 axles will be carefully inspected, and those

* Stiffness and lightness desired.

only will be accepted which are made and finished in a workmanlike manner, and which are free from cracks or unwelded seams.

Locomotive-tender and car axles to have journals swaged, and all axles to be centred with 60-degree centres.

PASSENGER-CAR AND PASSENGER-LOCOMOTIVE AND TENDER-TRUCK AXLES.

Axles must be made of steel and be rough-turned throughout.

Two test pieces will be cut from an axle, and the test sections of five-eighths inch diameter by two inches long may fall at any part of the axle, provided that the centre line of the test section is one inch from the centre line of the axle. Such test pieces should have a tensile strength of 80,000 pounds per square inch, and an elongation of twenty per cent. Axles will not be accepted if the tensile strength is less than 75,000 pounds, nor the elongation below fifteen per cent., nor if the fractures are irregular.

FREIGHT-CAR AND FREIGHT-LOCOMOTIVE AND TENDER-TRUCK AXLES.

STEEL.—Steel axles for freight cars, and freight-locomotive, and tender trucks, will be subjected to the following test, which they must stand without fracture :

*Axles Four Inches Diameter at Centre.*—Five (5) blows at twenty feet of a 1640-pounds weight, striking midway between supports three feet apart ; axle to be turned over after each blow.

*Axles Four and Three-Eighths Inches Diameter at Centre.*—Five (5) blows at twenty-five feet of a 1640-pounds weight, striking midway between supports three feet apart ; axle to be turned over after each blow.

IRON.—Iron axles for freight cars, and freight locomotives, and tender trucks, are to be hammered ; new muck bar must be used, which must be thoroughly reworked at least once before piling for the axle ; it must be tough, fibrous, uniform, and free from scrap. If reworked by rolling, the slabs must not be greater than three-quarters inch thick when piled for the axle ; if reworked by hammering, the power of the hammer must be sufficient to work the pile to its centre to the satisfaction of the P. R. R. Inspector. Such axles will be subjected to the following test, which they must stand without fracture :

*Axles Four Inches Diameter at Centre.*—Three (3) blows at ten feet and two (2) blows at fifteen feet of a 1640-pounds weight, striking midway between supports three feet apart ; axle to be turned over after each blow.

*Axles Four and Three-Eighths Inches Diameter at Centre.*—Three (3) blows at twelve feet and two (2) blows at eighteen feet of a 1640-pounds weight, striking midway between supports three feet apart ; axle to be turned over after each blow.

## SPECIFICATIONS FOR TANK STEEL.

All tank steel will be ordered subject to the following specifications :

1st. No sheet will be received that shows mechanical defects.

2d. A test strip from each sheet, taken lengthwise of the sheet, and without annealing, should have a tensile strength of 60,000 pounds per square inch and an elongation of twenty-five per cent. in a section originally two inches long.

3d. Sheets will not be accepted if the test shows a tensile strength less than 55,000 pounds or greater than 70,000 pounds per square inch, nor if the elongation falls below twenty per cent.

4th. Manufacturers must send one test strip for each sheet (this strip must accompany the sheet in every case); both sheet and strip being properly stamped with the marks designated by this company, and also lettered with white lead to facilitate matching.

SPECIFICATIONS FOR BOILER AND FIRE-BOX STEEL.

All specifications for boiler and fire-box steel heretofore issued are hereby annulled, and superseded by the following:

1st. A careful examination will be made of every sheet, and none will be received that show mechanical defects.

2d. A test strip from each sheet, taken lengthwise of the sheet, and without annealing, should have a tensile strength of 55,000 pounds per square inch, and an elongation of thirty per cent. in section, originally two inches long.

3d. Sheets will not be accepted if the test shows a tensile strength less than 50,000 pounds or greater than 65,000 pounds per square inch, nor if the elongation falls below twenty-five per cent.

4th. Should any sheets develop defects in working, they will be rejected.

5th. Manufacturers must send one test trip for each sheet (this strip must accompany the sheet in every case); both sheet and strip being properly stamped with the marks designated by this company, and also lettered with white lead to facilitate matching.

THEO. N. ELY,
*General Superintendent Motive Power.*

Captain O. E. MICHAELIS, *Ordnance Department U. S. A.*

Mr. Dorsey has succinctly stated the advantages of mild steel for ordnance purposes, and in doing so he has reflected the views of the most prominent steel experts of the day. As an engineer, appealing to a technical audience, he has apparently not deemed it necessary to fortify his correct conclusions by adducing well-known data; in this he has wisely trusted to the knowledge of his hearers. Still, it may not be out of place to state a few pertinent facts, the correctness of which is unimpeachable. Mr. George Ede, of the Royal Gun Factories Department, Woolwich Arsenal, in his little work, "The Management of Steel," though issued in 1867, yet in 1884 quoted as "valuable" by Mr. William Metcalf, unquestionably, since Holley's death, our most prominent scientific and practical steel expert, in addressing those "who are more attentive to authority than reason, and who inquire by whom a process is used rather than what are its merits," states that the toughening of large masses of mild cast-steel

blocks and tubes is in daily practice at Woolwich. After describing in detail the process of cooling the steel in oil, Mr. Ede adds: "Exceeding toughness is the result of the operation, while it is thus made much higher in tensile strength, offering a much greater resistance to compression. It is also harder and more elastic, and requires a much greater force to break it under the hammer, and it is not worn or indented so readily as when received from the tilt or annealed. . . . . Steel containing much carbon oil will harden the surface very much more than its internal parts, so that it will resist the file; but beneath the surface it will be quite soft. In steel containing a less proportion of carbon there appears to be very little difference between its external and its internal parts. In theory there cannot be much difference between the external and the internal parts of steel containing such a small amount of carbon and not possessed of hardening properties, or only in a slight degree; and in practice the theory is proved to be correct." Again, in reply to a supposititious question, this practical steel-ordnance expert says: "It may, perhaps, be asked by those who are not practically acquainted with the hardening and tempering of steel, if it would not be better to make a solid shot entirely of highly carbonized blister, shear or cast steel, and subsequently harden and temper it. The answer is, thick lumps of highly carbonized steel, whether hardened in oil or pure water, or water with a film of oil upon its surface, cannot be hardened without becoming fractured either internally or externally." The exhaustive series of experiments carried on for a period of five years by Professor John W. Langley, Professor of Chemistry, University of Michigan, and Mr. William Metcalf, of Pittsburgh, are authoritative; the results were presented to the American Association for the Advancement of Science by Professor Langley, and to the American Institute of Mining Engineers by Mr. Metcalf, and are familiar to all interested in the subject. These experiments were undertaken to obtain commercial information, without any reference whatever to gun construction, and hence are certainly free from even the slightest taint of "bias." The following general laws were indicated by these experiments:

I. The specific gravity of the steel ingot varies directly with the quantity of iron present.

II. The greater the quantity of carbon present, the greater the amount of work necessary to produce change of form.

III. The greater the quantity of carbon present, the greater is the change in volume due to a change of temperature.

Upon this last deduction Mr. Metcalf makes this comment: "This is perhaps the most important observation that can be made on this series of experiments, as it shows us why it is that high steel is so much more liable to crack and break in manipulation than low steel. We generally say one is brittle and the other is ductile; we now know that the rate of expansion per degree of temperature is much less in low steel than in high steel. Therefore, low steel is much less liable to injurious internal strains than high steel." Another conclusion from these experiments has a very important bearing upon the question under discussion: "If steel of moderately high carbon be repeatedly hardened, it will continue to increase in volume until ruptured." I believe that this explains the reported failures, without apparent cause, of many high-steel guns. Professor Langley has demonstrated that sudden cooling from even a boiling temperature causes a hardening effect. Do we not approximate this condition in firing guns—especially where a wet sponge is used? It seems to me that this successive hardening, with its accompanying increase of volume, may in time carry the tension members of the built-up gun beyond their elastic limit, and rupture ensues under slight provocation. We must bear in mind that the slow cooling of a steel gun after firing is virtually an annealing process, and that thereafter, under favorable conditions, it is again prepared for the hardening process, a not improbable concomitant of battle use. In this connection, I will cite a result reached by Mr. L. L. Buck, the engineer in charge of the renewal of the suspended superstructure of the Niagara Railway Suspension Bridge, in his test of the steel he proposed to use, which is of some service to us interested in gun construction. Mr. Buck desired to ascertain the capacity of specimens, running as high as .48 carbon, having an ultimate strength running over 100,000 pounds, with a stretch of less than eight per cent. in ten inches, for *resisting shocks*. His conclusion, from his elaborate and careful investigation, though *aliunde* as concerned his immediate subject, was that "high steel, if used in structures where the dead load considerably exceeded the live load (in the case of the tensile members), might be perfectly reliable, while in case the dead load was small and the live load large in proportion, it would be dangerous."

The application is obvious. It cannot be doubted that high steel, as already explained, is more liable to dangerous internal strains than low steel; and I am convinced that these latent forces, imprisoned in

the finished product by "cobweb" chains, easily swept away by favoring circumstances, explain the mysterious casualties so frequently reported. Some of these masses are veritable Prince Rupert drops, in apparent equilibrium, solid and strong, but on application of the proper slight disturbing element they crumble into dust. At the Annual Convention of the American Society of Civil Engineers, Buffalo, June 10, 1884, I read a paper (copy enclosed) on "The Heavy-Gun Question" (*Transactions*, Vol. 13: July, 1884). I advocated the trial of a hollow-cast, open-hearth steel gun, and subsequent study of the subject has strengthened my belief in the entire practicability of this method of gun construction. By the expenditure of one-quarter of one per cent. of the amount necessary for our efficient armament a final, present test can be encompassed; if decisively successful, at least half a dozen large plants would at once enter upon the casting of the heaviest guns, which could be furnished with a fair profit at two hundred dollars per ton. The most recent investigations have shown that in order to obtain the greatest chemical homogeneity, the very soul of modern structural steel, in hollow or annular forms, the largest possible cores should be used, and the mass cooled from within—a condition fully met by the Rodman process. The anticipated difficulty of mould-instability, penetrating sand-patches and so forth, need no longer be feared, for I can bear witness, after personal examination, that Mr. Hemphill's sheet-iron casing is an almost certain remedy. We have to-day at Cleveland a sufficient furnace capacity to turn out the required casting, and at South Boston an adequate machining plant. For our open-hearth bath we have available a pig metal, free from silicon and manganese, carrying no sulphur at all, and guaranteed to be below the point .015 in phosphorus; this, with the best charcoal blooms for softening, including ferro-manganese and ferro-silicon additions, would bring up the cost of the melt in the ladle to about $70 to $75 per ton—high, but not excessive for the grade. Is not the time ripe for the trial of a method seconded by almost all the prominent steel experts in the country? Washington, in his Annual Message, January 8, 1790, says: "The safety and interest of the people require that they promote such manufactures as tend to render them independent of others for essential, particularly for military, supplies." Should the casting of steel guns be successful, Washington's charge would be effectually carried out, for soon—very soon—every large steel plant in the country would have capacity for turning out the heaviest guns.

A few words relative to the construction of guns of concentric cylinders of mild steel. I brought this matter up at the Annual Convention of the American Society of Civil Engineers, held at Deer Park, Md., in June, 1885. Should casting prove a failure, then we have in this method of building up guns a purely American idea—one that, so far as limited experience and careful study will permit, holds out strong hopes of success. Mr. F. J. Seymour, Superintendent of Brown Bros. Works, at Waterbury, Conn., was in special charge of the production of the cartridge metal to be supplied us at Frankford Arsenal, and, being entrusted with the inspection of the product, I became well acquainted with him. He conceived the idea that large disks of mild steel might be treated very much like copper, and he proposed to draw or fold tubes, initially hot, finally cold, thus producing true cylinders free from defect, for externally and internally they could be carefully scrutinized, and of greatly increased strength —a result of the condensing effect of the cold flow. I was struck with the simplicity of the idea, and saw its applicability for lining our stock of cast-iron guns. A subsequent visit to Cleveland convinced me that the plan was practicable. These superimposed cylinders, forced or brazed upon each other, yield all the advantages of the favored circumferential wire winding, affording the greatest tangential resistance, and, in addition, offering a maximum longitudinal resistance, the tensile strength of the material, the goal for which the advocates of wire-wound guns are striving. I enclose herewith rude tracings of a 5-inch and 12-inch built-up rifle, and of the proposed method of converting a cast-iron gun—sketches presented at the meeting mentioned. With two original, apparently feasible plans of constructing guns at command, ought we not at least to make the attempt to deviate from still unended, though well-trodden, paths? During the past few years Mr. Dorsey has made a specialty of the study of steel for structural purposes, and on various occasions, at meetings of societies of which we are both members, I have been much indebted to him for valuable information, not elsewhere readily obtainable, upon this most interesting and important subject.

THEODORE COOPER, *Consulting Engineer, 35 Broadway, New York.*

Each of the various grades of steel has a special field, for which it is the best, whether it be that which approximates the diamond in hardness, or that which almost equals lead in its pliability. To say

soft or mild steel is the most suitable for guns or any other purpose, because it is the best for boilers, is fully as erroneous as saying hard steel is suitable for boilers because it is the most suitable for tools and other purposes.

The suitability of a particular grade of steel for any purpose, or the best steel to use for a special object, must be finally determined by experiment and actual use.

By these means we are able to state approximately that certain grades are, under our present experience, the best for boilers, rails, machinery and the various classes of tools. We are, however, even in these special fields, constantly gaining in knowledge by the study of defects and causes of failure.

It is not possible to establish by *à priori* reasoning the best grade of steel for some new and untried purpose; but we can, by a careful study of the properties of the various grades of steel, processes of manufacture through which the material must pass before it reaches its final condition, and the duties to be performed by the material in its new purpose, determine the direction in which we may hope for the most suitable material.

The properties most affecting the suitability of the material are the tensile strength, ductility, elasticity, hardness, purity and homogeneity.

The last two, purity and homogeneity, may be assumed as essential for all purposes where the best results are desired. The other properties, in their infinite varieties, are the ones which, other things being equal, determine the appropriateness of the material.

If these properties increased together, the solution would be very simple; but such is not the case: the tensile strength and hardness increase as the ductility decreases. So, where we desire all of these qualities, we must balance their relative merits or desirability, and select the one appearing to give the best result for our particular purpose.

We must, at the same time, consider well the service to be done, and also the effects that the processes of manufacture may have upon the apparently desirable grade of metal. For boilers we must not only select a grade of steel that will properly perform the duty of resisting the internal pressures, but one which will bear the severe manipulations of bending, flanging, punching, riveting, caulking, etc., with the least injury, and also can be subjected to the trying conditions of heat and cold without serious effects.

For bridges, where it is very tempting to strive for the strongest class of steel, we are in like manner compelled to seek the highest grade which can be put through the manipulations of the several processes with the least permanent injury, and also which *after completion* will be the best to resist the shocks and vibrations of the rapidly moving loads.

For castings or heavy forging we must in like manner not only bear in mind the final purpose for which it is to be used, but the liability of the particular steel to be injured by the forming and cooling of such masses.

Much misunderstanding and false conclusions have arisen from the misuse of the terms tensile strength, ductility and elasticity.

By *tensile strength* we mean the ultimate or breaking strength of a prismatic bar of the metal under the steadily increasing strain of a testing machine continuously applied until rupture occurs.

The form and size of the specimen have a very great influence upon the final result. The difference of the strength of specimens and the strength of large masses from which the specimens may be cut is also very great. The suddenness of the application of the load is also an important factor. A piece loaded repeatedly far below the amount which one continuous test would give as the breaking strain, will finally rupture. The number of loadings governs, therefore, the maximum strain to which the piece can be repeatedly strained.

By *ductility* we mean the permanent deformation or elongation that the piece undergoes, in one continuous testing, up to rupture. It is usually measured in percentage upon a length originally eight inches long.

3. By *elasticity* we mean the amount of deformation or elongation that the piece can undergo without injury or permanent alteration of form or dimension; returning to its original shape and size upon relaxing the deforming forces.

By *hardness*, the relative resistance to wear or abrasion.

The extent to which any piece can be strained without producing any permanent alteration of form is called the *limit of elasticity*. This is usually determined in the testing machine by a series of continuous applications.

That in practice, where our applications of the loads are not statical, as in the testing machine, the limit of elasticity may be different from the usually accepted elastic limit, is very probable. As before stated, neglect of the effects of repeated loads and of impulsive loads instead of statical ones has led to much error.

The knowledge we possess to-day of the strength of materials has been obtained primarily from the practical use of such materials in their various forms, rather than from the study of the numerous tests made upon such materials. Failures in practice and tentative changes of form and proportions have led us to the use of certain shapes and allowed strains. The testing machine has followed these results and analyzed the principles underlying these forms and allowed strains.

As we study these, we must see that it is not a question solely of tensile strength, but of the amount of work a particular form or material can do under the special forces acting upon it.

To resist impulsive forces—and we may safely assume that in practice we seldom have simple statical forces to resist—it is necessary to meet them by *work* done. The strongest material from the tensile-strength point of view may be the weakest for our purpose. A hempen cable would take with ease the surging of a vessel, where a cast-iron chain or bar of many times its tensile strength would snap in pieces.

The work that a hempen cable can perform is of two kinds. First, if it is such that the cable remains uninjured after the duty is performed, we can call it the *elastic work;* for the cable has not been stretched beyond its elastic limit, and has returned to its original length and condition. Second, the cable may be unbroken, but less able to perform continued duty of the same kind. It has then performed work by permanently stretching, and will ultimately break upon repetitions of the same duty.

Now, every material has, in like manner, an ability to resist impulsive forces by its elastic work and by its work of stretch or deformation.

Structures that perform their duty by the elastic work only so that they are as fully prepared to resist a repetition of their loading as in the beginning, can be classed relatively as permanent structures.

Structures, however, which are less able to resist repetitions of the load can be classed as temporary structures. Such structures may be worked up to higher strains as the number of possible repetitions of their duty is less. In all such structures relative economy, convenience of size, etc., govern the selection of the proper material and proportions.

In selecting the proper material for any purpose, therefore, we must carefully consider, not its tensile strength only, but its ability to do the two kinds of work and to resist for a desired number of times a certain duty.

Having thus briefly explained the general principles governing the selection of the proper material, let us consider them briefly as applied to the gun question.

Now, a gun under severe service charges can be considered as a temporary structure. Its life, relative to its cost and weight, is its measure of value.

Eliminating for the present all considerations of processes of manufacture, and the strains induced by the same, we can assume that the most destructive actions upon a rifled gun are the overstrains due to the suddenly expansive gases, erosion and abrasion. To resist the erosion and abrasion, it would seem, to one who has given no special study to this subject of guns, as assumable that it is desirable to have the hardest material consistent with its ability to best resist the impulsive forces of the explosive.

As before explained, the impulsive forces must be met by an equal work done by the material, consisting, first, of the work of elasticity, and secondly, of the work of permanent deformation.

Bearing in mind that the capacity for elastic work is approximately the same for each application of the forces, while the work of deformation, as usually measured by the tensile strength and elongation, is a definite quantity from which each discharge is withdrawing a portion, it becomes clear that we should aim toward the material having the greatest capacity for elastic work. The elastic work may be used an indefinite number of times, but the work of deformation but once.

As we pass toward the higher steels, the capacity for elastic work increases almost as the square of the tensile strength; or, in other words, a steel with double the tensile strength of another grade has approximately four times the elastic work of the lower steel. For any assumed duty, the greater the work done by the elasticity the less work remains to be overcome by the work of deformation.

Practically, the amount of allowed deformation, as measured upon the bore of a gun, must be very small. We therefore cannot depend much upon the work of deformation to resist the impulsive strains of the gases, but mostly, if not entirely, upon the elastic capabilities. We should, however, have a material possessing a certain reserve of deformation power or work, to provide against disastrous explosion of the gun in actual service.

It therefore seems to me desirable to obtain the highest steel which can give the desired reserve of deformation, and which can be put into the form of a finished gun without injurious strains from the

processes of manufacture, and which can stand the heating and cooling of actual service without injury.

That such a gun can be made in preference from what is called hard steel, instead of soft steel, I fully believe.

I do not wish to convey the idea that the steel called for under the Naval Specifications is therefore the best, but only that a high steel in preference should be sought after.

In one thing I can agree with the author: The only true and possible method of determining the best steel must ultimately be by actual construction and service of the gun.

With full faith in the ability of our manufacturers to develop new and better methods of manufacturing, and in connection therewith, to assist in the selection of the best grade of material, I claim that an effort should be made to combine, without unnecessary trammels, the technical knowledge of the manufacturer and the ordnance officer.

The past history of the Fort Pitt Foundry, in connection with the ability of a Rodman under like circumstances, can be repeated for steel guns.

If a prospective order for a number of guns could be assured our manufacturers upon the success of sample guns, an incentive would be given which would, I fully believe, produce excellent results. Instead of following simply in the same paths as European governments, we should at least give an opportunity for the development of that hard common sense and practical ingenuity, free from the trammels of blind precedence, for which our manufacturers and engineers have become renowned in all the branches of civil construction.

Allow full latitude to manufacturers in the selection of their material and in their processes of manufacture, holding them solely to the desired requirements in the finished gun. The practical knowledge of Whitworth, Armstrong, Krupp and others, has been a strong feature in the advancement made in European countries in the gun question. Why should not American metal-workers have also a fair field in the same direction?

Personally, I do not believe we have even yet exhausted the possibilities of our cast iron; and I am not yet of the opinion that, with a good opportunity to develop the proper method of casting steel guns, an equally excellent result cannot be made with this metal that formerly we were able to do with our cast iron.

Asking your indulgence for these incomplete and somewhat crude remarks, I tender you my thanks for the invitation to discuss this paper.

## NEWPORT BRANCH.

DECEMBER 29, 1886.

COMMANDER C. F. GOODRICH, U. S. N., Vice-President of the Naval Institute, in the Chair.

The paper of Mr. Edward Bates Dorsey, C. E., was read by the Corresponding Secretary of the Branch, and the following discussion took place:

Professor RAPHAEL PUMPELLY.—*Mr. Chairman and Gentlemen:* I regret that it will be impossible for me to be present at the reading of Mr. Dorsey's very timely warning. While not familiar with the requirements of heavy ordnance in regard to qualities in steel, nor with the intentions of the Government in the matter, I fully agree with Mr. Dorsey on the general question of the decrease of the trustworthiness as the thickness of hard-steel masses increases. The more rapid increase of volume near the surface than in the interior produces, as is well known, a great textural strain.

It may be an open question whether in a thick body, even of an ideally perfect quality of steel, the oil-bath can restore the desired equilibrium; but, in view of irregularities that practically exist in the various steels, there would seem to exist a real danger that in this unequal strain produced in hardening, there may be produced in thick articles minute ruptures, or permanent disturbances, equally undesirable with those formed in cold-punching or shearing, and which, of course, would not be remedied by the oil-bath. This is one of the points that can be settled only by thorough experiments on the various steels.

Colonel GEO. H. ELLIOT, *Engineer Corps U. S. A.*—I much regret that I cannot be present at the meeting of the Institute this evening, to listen to the discussion of Mr. Dorsey's interesting and valuable paper, but I send you herewith some extracts from a recently published paper by Mr. Benjamin Baker, of the Forth Bridge R. R., entitled *"Some Notes on the Working Stress of Iron and Steel," which may be interesting to the Institute.

Although Mr. Baker's experiments were not made in connection

*Engineering News and American Contractors Journal, 16, 397-399; Dec. 18, 1886.

with the construction of heavy guns, they appear to tend to confirm Mr. Dorsey's conclusions.

"Wöhler's experiments on the so-termed 'fatigue' of metals are well known. The writer, wishing to satisfy himself as to the behavior of modern structural steel under different stresses, has, during the past few years, carried out experiments in some respects similar to, and in others differing from, those of Wöhler, and has also made analogous tests of hard steel and of iron. The experiments may be roughly classified under four heads: (1) Rotating spindles, with a weight at the free end, causing alternate tension and compression on the fibres as the spindle revolves; (2) Flat bars bent in some cases one way only, and in other cases both ways; (3) Specimens so designed as to give alternate direct tension and compression on small pieces of metal; and (4) Full-sized riveted girders.

SERIES NO. 1.

*Soft Steel.*

| | Number of Revolutions. | Stress per Square Inch. | Factor $a$. | Factor $b$. |
|---|---|---|---|---|
| 1 | 40,510 | 36,000 | 1.75 | 2.45 |
| 2 | 60,200 | 36,000 | 1.75 | 2.45 |
| 3 | 68,400 | 34,000 | 1.84 | 2.56 |
| 4 | 92,070 | 34,000 | 1.84 | 2.56 |
| 5 | 107,415 | 34,000 | 1.84 | 2.56 |
| 6 | 128,610 | 34,000 | 1.84 | 2.56 |
| 7 | 155,295 | 34,000 | 1.84 | 2.56 |
| 8 | 14,876,432 | 26,000 | 2.42 | 3.4 |
| | | *Hard Steel.* | | |
| 9 | 5,760 | 67,000 | 1.88 | 2.82 |
| 10 | 7,560 | 65,000 | 1.93 | 2.90 |
| 11 | 14,600 | 53,500 | 2.36 | 3.45 |
| 12 | 16,300 | 53,500 | 2.36 | 3.45 |
| 13 | 26,100 | 46,500 | 2.72 | 4.10 |
| 14 | 32,405 | 51,000 | 2.40 | 3.60 |
| 15 | 157,815 | 40,500 | 3.03 | 4.55 |
| 16 | 472,500 | 34,000 | 3.70 | 5.55 |
| | | *Best Bar Iron.* | | |
| 17 | 108,160 | 34,000 | 1.70 | 2.38 |
| 18 | 110,000 | 35,000 | 1.66 | 2.32 |
| 19 | 141,750 | 34,000 | 1.70 | 2.38 |
| 20 | 389,050 | 32,000 | 1.90 | 2.65 |
| 21 | 408,000 | 30,200 | 2.00 | 2.80 |
| 22 | 421,470 | 32,000 | 1.90 | 2.67 |
| 23 | 480,810 | 31,000 | 1.95 | 2.75 |

"The above series includes a representative number of the writer's experiments with rotating spindles. As a rule, the spindles were one inch diameter and projected about ten inches from the end of the revolving shaft in which they were fixed. A speed between fifty and sixty revolutions per minute was maintained day and night.

"The 'soft steel' was fine rivet steel having a tensile strength of from 60,000 to 64,000 pounds per square inch, and an elongation of 28 per cent. in 8 inches. The 'hard steel' was a high-class 'drift' steel having a tensile strength double the above, and an elongation of one-half the extent. The 'iron' was the best rivet iron, having a tensile strength of from 58,000 to 61,000 pounds, and an elongation of 20 per cent.

"Factor *a* is the ultimate tensile strength per square inch of the specimen divided by the calculated stress upon the outside fibres, due to the load on the end of the projecting bar. Factor *b* is the ratio of the static load required to bend the bar a moderate amount beyond the elastic limit, to the load actually imposed upon the revolving bar. These definitions will be made more clear in further references to the table.

SERIES NO. 2.

*Soft Steel.*

| No. of Bends. | | Stress per Square Inch. | Factor *a*. |
|---|---|---|---|
| 24 | 12,240 | 44,000 | 1.59 |
| 25 | 12,325 | 44,000 | 1.59 |
| 26 | 12,410 | 44,000 | 1.59 |
| 27 | 18,100 | 42,000 | 1.67 |
| 28 | 18,140 | 42,000 | 1.67 |
| 29 | 72,420 | 36,000 | 1.94 |
| 30 | 147,390 | 34,500 | 2.03 |
| 31 | 262,680 | 34,000 | 2.05 |
| 32 | 1,183,200 | 27,500 | 2.55 |
| 33 | 3,145,020 | 34,500 | 2.03 |

*Best Bar Iron.*

| | | | |
|---|---|---|---|
| 34 | 184,875 | 34,000 | 1.68 |
| 35 | 250,513 | 34,000 | 1.68 |
| 36 | 3,145,020 | 34,000 | 1.68 |

"The above series is a selection from the writer's experiments with flat bars bent laterally. Generally the bars were one inch wide by one-half inch thick, and thirty-two inches long between the bearings.

"The steel specimens were cut from the tension member plates of the Forth bridge, and had a tensile strength of about 70,000 pounds per square inch, and an elongation of twenty per cent. in eight inches. The iron specimens were rolled bars.

"A careful consideration of the results of the preceding experiments will, the writer thinks, illustrate many points of interest to practical engineers. Experience has shown that screw shafts and axles generally, made of the finest quality of high-tension steel, are not practically as strong as when made of soft steel, having theoretically, perhaps, little more than half the strength of the former.

"Referring to Series No. 1, we find, comparing Experiments Nos. 8 and 14, that under working stresses in each case equal to about forty per cent. of the ultimate strength, the hard steel failed with only 32,445 revolutions, while the soft steel stood 14,876,432. Again, comparing Experiments Nos. 16 and 23, it will be seen that with practically the same number of revolutions the hard steel, though more than double the tensile strength of the iron, broke under a working stress only ten per cent. greater. It is impossible, in the face of results such as these, to contend that the ordinary laboratory tests of a metal give any adequate measure of its value as a material of construction.

"Iron of high quality holds its own, as compared with mild steel, in these experiments, and this is consistent with the general experience as to the driving axles of locomotives, which are subject to repeated bendings of considerable severity. Certain of the soft-steel specimens would have given higher results had they not been turned down, as fracture occasionally appeared to have been accelerated by the slight tool-marking. On the other hand, No. 8 stood exceptionally well, although it was a turned-down specimen. All of the hard-steel bars were put in with the skin on.

"An illusion entertained by some engineers that alternating stresses are destructive only if the stress exceeds the elastic limit, is effectually disposed of by these experiments, because none of the stresses in question exceeded the said limit, and some of them were very far below it.

"Thus, in Experiment 16, the working stress was but one-half of the stress at the elastic limit under direct tension, and only one-third of the stress at the elastic limit of the material when under transverse stress, which was really the condition of the specimen in the experiment. Factor $b$, in the case of Experiment 16, has a value of 5·55,

which means that less than one-fifth of the static weight required to bend a hard-steel pin a small amount, will suffice to fracture the pin if the stress be alternating, as in the case of the pins of connecting-rods, for example. If we take what is usually termed the breaking load, or, say in a ductile material like steel, the stress which would deflect the bar as a beam an amount equal to half the span, then the load which ultimately broke the bar in Experiment 16 was only one-seventh of the original static breaking load—a sufficiently remarkable result.

"Other points of interest may be referred to in connection with Series 2. In general the bars were tested in pairs, so that when one bar broke its companion could be otherwise tested and examined. For example, the companion to No. 28, after being subjected to 18,140 bendings, was tested for tension, and failed with 48,000 pounds per square inch, and 2.6 per cent. elongation, the original strength of the steel being 70,000 pounds and 20 per cent. elongation.

"Again, the companion of No. 32 was, on close examination, found to have a flaw like those found in crank shafts. Nos. 33 and 36 were companion bars, bent one way only, so that the stresses were not alternating; hence the largely increased endurance.

"They were both taken out before actual fracture, but with deep-set flaws, clearly illustrating that the cause of failure under repeated stresses is very frequently not so much a gradual deterioration or crystallization of the metal, as the establishment of small but growing flaws. This, of course, is well known to locomotive and marine engineers; and on some railways it is the custom to run crank axles until the incipient flaw is detectable, and then to hoop the web of the cranks; whilst marine surveyors do not condemn a shaft necessarily on the first appearance of a flaw, but license it to be run for a further definite period.

"Another noteworthy fact illustrated by these experiments was, that a structure or piece of mechanism may be subjected to a repeated stress equal to ninety per cent. of that which would break it, and yet specimens cut from the metal may exhibit no signs whatsoever of deterioration. The broken half of nearly every specimen in Series No. 2 was tested by the writer with that result.

"Thus, as the stress was applied at the centre of the bars, it followed that at a point ninety per cent. of the half span from the bearings the stress would be ninety per cent. of that which broke the bar.

"Although the bars broke short off at the centre at the point referred

to, they could invariably be bent double without fracture. Having reference to this fact, and to the fact that the tensile strength was also a little affected, it is clearly hopeless to expect to learn much from testing specimens of metal from structures or machines which have been long in use. Unless the experimenter happens to hit off the right moment immediately preceding the commencement of failure, he need not expect to learn much from the behavior of the metal in the testing machine. Professor Kennedy, in an interesting and instructive lecture recently delivered before the Royal Engineers at Chatham, has given the results of tests of forty-seven pieces of iron and steel which had either been in constant use for many years until they were so much worn as to require renewal, or which had been broken in actual use; but in no case did he find anything distinctly pointing to a weakening effect due to actual fatigue.

"This is exactly the result which the writer's experiments would have led him to anticipate; but it by no means follows that the very piece of metal tested by Professor Kennedy, and found uninjured, would not have broken a few days after in actual working. A man of seventy years of age may be as sound as he was at twenty, but the fifty years have told on him nevertheless, and the breakdown is certainly near and may be sudden. Having referred to Professor Kennedy's lecture, it is necessary, perhaps, for the writer to say that he does not agree in some conclusions set forth therein. Thus, Professor Kennedy expresses his belief that the failure of coupling-rods occurs as much by the gradual disintegration of the dirt between the laminations, and the oxidation of the iron, as by vibration and repetition of load; and that a homogeneous material like steel remains comparatively uninjured by repetition. This, of course, is negatived by the results of the experiments cited in the present paper. Professor Kennedy further says: 'If a load exceeding the limit of elasticity be applied a considerable number of times, the bar will be actually broken; but, at the same time, we know that if any load exceeding the limit of elasticity be but once applied, the structure to which the bar belongs is distorted and rendered useless.' This, the writer thinks, is a dangerous fallacy, tending to delay the application of truly scientific principles to the design of structures and mechanism.

"In concluding this necessarily very hurried and imperfect paper, the writer would like to bear testimony to the admirable behavior of a very good friend of his—*mild steel.* During the past three years

he has had to deal with about 24,000 tons of that material, and to submit it in many cases to very harsh treatment. He has had more cases of so-termed 'mysterious fractures' with the few tons of wrought iron used for certain temporary purposes, than with the whole 24,000 tons of steel. The rest of his experience may be of interest to brother members of this society who now are, or will doubtless be, large users of mild steel; and the testimony is perhaps of the greater value as the work at the Forth is pressed on day and night, and no precautions are taken which would not equally be necessary were the material of the highest class of Lowmoor iron, costing double or treble the price of the steel."

Colonel E. H. HEWINS.—Some years ago I was entrusted with the building and charge of operating a testing machine, and perhaps my experience with it may be of some value to you. The machine was one of the largest, and undoubtedly the most accurate large testing machine in this country until the construction of the Government machine now at the Watertown Arsenal. We could test up to one hundred and fifty tons, dead pull, and with that amount of strain on we could measure accurately increments of less than one-quarter of a ton. My experience may serve to assist you in discovering the source of the discrepancies among your data. At the outset, when using this machine, we met with the same apparently conflicting results, and on consideration I concluded that they were due to our inability to observe and record accurately. Soon after, we constructed an automatic registering apparatus, and the conflicting results largely disappeared. These experiments were made on iron. Hence I cannot say whether or not as concordant results would have been obtained with steel. Comparisons of the results of the tests of different specimens cannot be so intelligently made by means of tables of figures as they can by the use of diagrams. By the use of the latter the comparisons may be instituted with readiness and accuracy. These diagrams bear the same relation to the action of the test specimens that steam-indicator diagrams do to the action of the steam within the cylinder, and those we made were similar to those produced by Prof. Thurston.

These tests were made on long bars—longer, I suppose, than would be necessary for any such purpose as the steel under discussion would be used for. Sometimes bars thirty feet in length, intended for bridge-building, were tested. I have broken such bars with 140 to 150 tons

strain upon them. In the diagrams taken, the vertical direction represented the strain upon the bar, and the horizontal the elongation of the bar. (The method used was illustrated on the blackboard.) The portion of the resultant curve just before reaching the elastic limit seems to be the most important for consideration, since strains within this limit are those to be dealt with in practice. When we go beyond the elastic limit the curve takes a sudden change of direction of nearly 90°. Sometimes the diagram will take a form showing a continually increasing strain until the bar breaks short off with the highest strain reached. Sometimes the maximum is not the breaking strain, but as the bar extends the strain reduces more or less. I cannot express an opinion as to which form of diagram would indicate the best quality of metal for gun purposes or for the different parts of guns. If you have diagrams like this and wish to compare the specimens, you can do so with greater certainty than is possible in any other way. For bridge-work it is one of the best ways of determining whether or not the bars are uniform. If you are going to have several bars parallel to each other, or you are going to build up a barrel of hoops, each should with certainty receive its strain at some predetermined time, for if they have different moduli of elasticity and receive their strains at the same time, one bar or hoop will expand more under the same strain than another, and they will ultimately be broken in detail. I do not mean that the elasticity need be the same in the different hoops, but by this means we could select hoops to bear the strain which is to be put on them. This question of the modulus of elasticity, as well as that of the elastic limit, is of the first importance. The elastic limit might be the same in two bars, yet one bar might extend twice as far as the other under the same strain. By the diagrams certain results may be recorded which no human eye could have observed, and from them we can obtain the modulus of elasticity, the limit of elasticity, the maximum strain to which the bar had been subjected, the breaking strain, and the elongation. The specific gravity of the metal, both before and after testing, should be ascertained, for much can be predicted concerning the adaptability of the metal if this be known. In testing metals the specimens should be as nearly alike in dimensions as possible for convenience of comparisons. If the sectional area were twice as large in one specimen as in another, the diagram would be twice as high.

In my opinion the question of molecular condition is one of the first importance. Unless you know that, you cannot tell what internal

strains there may be in it, but undoubtedly the oil-tempering and annealing largely eliminate such internal strains. You cannot forge large masses under any hammer that is known without producing internal strains, and therefore it seems to me very important to employ hydraulic presses for forging. In this way only can the mass be forged to a uniform density, and this would leave less work for the annealing to accomplish, which process would thereby be made of more value in its final results.

Professor CHARLES E. MUNROE.—In discussing this paper of Mr. Dorsey's, we observe that he contents himself with assertions; but it cannot for this reason be presumed that he is not fortified with data which he believes support his position; and, as a consequence, in order to meet him and disprove his statements, it will be necessary to present experimental data, or results of experience, which support the Ordnance Bureau and outweigh in value those he may quote. For, unless this can be done, it would be very unwise to go to large expense in the construction of ordnance, when the factors which form the important elements which determine success are yet disputed, and we had better confine ourselves within assured limits.

As for myself, I must confess that I am unprepared to furnish such data, nor have I been able to find them; but as some of our members have, in the performance of their duties, been called upon to study this problem, we shall have, I trust, before this discussion is completed, a full presentation of all the facts and data which have led to the adoption of the requirements set forth in the Bureau's specifications. If this be done, Mr. Dorsey will certainly have rendered the members of the Institute, and all of the many citizens of our country who are interested in the modern development of ordnance, a most valuable service. In fact, such examples as I have discovered in the limited time at my command seem rather to support Mr. Dorsey's position. Thus, for guns, we find in the reports of the Chief of Ordnance a complete account of the construction and proving of the 8-inch B. L. chambered rifles. These contained a wrought-iron tube. The breech receiver, block and band were made of English steel received from Firth & Co., Sheffield. The receiver and band were oil-tempered. The tests of these materials have been compiled in the following table, and show that the steel falls in the class defined as "hard":

* *Firth's Steel from Breech Block and Jacket of 8-Inch B. L. C. R.*

| Specimens. | Tensile Strength | Elastic Limit. | Elongation. | Part fr'm which Taken. |
|---|---|---|---|---|
| | Pounds | Pounds | Per ct. | |
| B. B. 7 inches long, 0.651 inch diameter..... | 66,000 | 21,000 | 21.43 | |
| B. B. 7 inches long, 0.652 inch diameter..... | 70,000 | 34,000 | 14.75 | |
| B. B. 7 inches long, 0.652 inch diameter ..... | 82,440 | 23,000 | 20.31 | |
| J. (O. T.) 3 inches long, 0.653 inch diameter... | 92,000 | 45,000 | 16.00 | Radially |
| J. 3 inches long, 0.651 inch diameter..... | 104,480 | 45,000 | 11.13 | |
| J. (O. T.) 3 inches long, 0.653 inch diameter... | 102,000 | 61,000 | 8.33 | Interior. |
| J. (O. T.) 3 inches long, 0.653 inch diameter... | 82,000 | 42,000 | 25.83 | Interior. |
| B. B. 10 inches long, 0.0652 inch diameter..... | 62,000 | 20,000 | 21.75 | |
| B. B.=breech block; J.=jacket; O. T.=oil-tempered. | | | | |
| *Ulster Iron for Tube 8-Inch B. L. C. R.* | | | | |
| Mean of four results..... | 49,250 | 26,750 | 30 | |

† Five of these guns were finished during the year ending June, 1881, and proved at Sandy Hook. One of them broke at the third round. This being claimed to have been due to the angular corners of the breech slot, these corners were rounded, the gun repaired and proved again. After 122 rounds the gun burst violently into numerous fragments, the tube being the least fractured. The average pressure of the last seven (and heaviest) rounds was 51,000 pounds, and the velocity 1710 feet. These pressures were not regarded as excessive, and were such as were quite likely to have occurred in the service use of the gun.

In discussing this failure, the Board held that the successful results previously obtained in the tests of the M. L. converted guns, and of an 8-inch B. L. R., with a Krupp fermeture (tried to 500 rounds), had justified the Bureau in the procurement of others of the same calibres, and that the result of this trial showed the difficulty of obtaining suitable steel for their construction.

It would be at least interesting if we could secure for comparison here the results of tests of the metal of this 8-inch gun whose successful action led to the order for the guns which failed.

In regard to the Krupp guns, which are regarded as almost standard, we find, in addition to the statement quoted by Mr. Dorsey, that Colonel Hennebert claims the material to be far from irreproachable; for, during the war with Bohemia, several Krupp field-pieces burst. After the war, in order to allay public agitation, trials *à outrance* were made, and these cost several young officers their lives. In 1868, General de Bœuf declared that several guns, firing ordinary charges,

* Report Chief of Ordnance U. S. A., pp. 395–408; 1881.
† *Ibid.* pp. 489–499; 1882.

had burst; nor can it be said that the Russian steel guns of to-day are safe. In fact, between 1867 and 1870 numerous accidents occurred in Russia, England, Germany and Italy, on land and on board ship. Colonel Hennebert says that during the Franco-German war 200 Krupp guns burst. At Versailles it was thought that if the French had held out a week longer, the German siege batteries would have been reduced to silence. It is equally certain that during the campaign on the Loire Prince Frederick Charles had twenty-four of his guns disabled by their own fire.

In regard to the question of unreliability in steel, we have, among others, the remarkable instance quoted from the *Engineer* in *Proc. Nav. Inst.* **12,** 241; 1886, where several boilers, constructed of steel which had passed all the tests required by the Board of Trade and Lloyd's, and which withstood all the processes of manipulation in the workshop, welding included, suddenly, after two and a half years' satisfactory use at sea, exhibited signs of a complete change in the character of the steel, which had become extremely brittle, and developed extensive fractures under very slight blows.

Again, in the *Engineer* for November 12 we find a steel plate, which possessed a tensile strength of 28.25 tons, an elongation of 21.25 per cent., and a composition of C. 149, S. 0.11, S. .042, P. .034, Mn. .574 per cent., developed a crack while being hammered in the boiler-shop. This was evidently mild steel, and it had passed inspection for the use to which it was to be put. The only peculiarity in working it was in heating it to a dull red heat for rolling; yet this seemed to have caused the metal to become brittle.

Mr. Dorsey has limited his criticism to the materials for hoops, but if his position be verified, his conclusions will apply equally to the tubes. Recent specifications require that these shall have a tensile strength of 80,000–72,000 pounds, an elastic limit of 35,000–31,500, and an elongation of 18–16.2 per cent. In considering the use of this material, we ought to bear in mind the results of the recent experiments of Sir Frederick Abel and Colonel Maitland.* Although not yet completed, they seem to show that the erosion of the tube by the action of the powder gases is markedly increased with the increase in size of the gun, and with increase in the hardness of the steel. This factor is so important a one in determining the life of a gun that it cannot be neglected.

In the course of these desultory remarks, permit me to say a word

**Engineer*, **62,** 292; Oct. 8, 1886.

about the methods of testing. As now conducted, it is the custom to take small samples—of two inches cross-section or thereabouts, and various lengths—from the mass, upon which to make the tests. Now, any chemist who has ever sampled a solid, heterogeneous mass for analysis, knows how very difficult it is to get two samples that agree exactly, and that, as a consequence, we must admit a large tolerance in our results. The same must be true in sampling a mass of steel for physical tests. On the other hand, I question if it is really known what numerical relation the tensile strength and other properties of a mass of steel bear to any unit section of the mass as tested by itself. We do know that as the cross-section diminishes, the tests for tensile strength give higher results. As for the tensile strength, so in the shocking test a small section of the specimen is employed. This test is conducted by allowing a hammer of known weight to fall through a measured distance upon the sample bar, this bar being supported near its two ends upon knife-edges, or over a hole in an anvil. This seems to me the most important test to which a metal for use in guns should be put, for the property of resisting a shock to a high degree is the most valuable property which gun metal can possess. In considering this subject, it has occurred to me that we possess in gun-cotton a substance which will enable us to test the resistance of a metal to shock, and that the test may be applied, not to a small sample, but to the original ingot from which the portion of the gun is to be formed. I have been led to this conclusion from observing the effect of gun-cotton upon the metals used in my experiments. Thus, I have found that when a ten-ounce disk of gun-cotton is placed unconfined upon plates of Swedish iron one-half inch thick and detonated, the iron is indented to a depth of about one-eighth of an inch, but the plates show little or no signs of fissuring. When a similar disk of gun-cotton is placed on a disk of hard steel two and a half inches thick, the steel disk is shattered to fragments. Should this suggestion be found worthy of consideration, we could easily determine by experiment the amount of gun-cotton required for the test, and the distance at which it is to be placed from the object. It may be urged that this test is in excess of any strain to which a gun charged with powder may be exposed; but the answer to this is that it is always good practice to expose an element in a structure to the test of a greater load than it will be called upon to carry when in use.

In closing, I would remark that if Mr. Dorsey's conclusions regarding the subdivision of the hoops be pushed to their ultimate consequences, we are led to the use of wire for the hoops.

Commander GOODRICH.—To profitably discuss a subject, it is necessary at the outset to adopt a system of definitions, so that the disputants may understand each other. The author's definitions are inadequate. He limits mild steel to that having a certain tensile strength coupled with a bending test. He mentions also that there should be a very low, but unstated, percentage of carbon.

It is hard to argue when the elements of the question are so obscure. Briefly, he accuses us of using treacherous metal in our new guns. Is this true?

Without dwelling on the significant fact that we have in this paper mere conjecture and absolutely no proofs, let me ask how the author would class steel having twenty per cent. elongation and forty per cent. stricture in a two-inch test specimen? Surely not as hard. Yet these are the average characteristics of our eight-inch gun-hoop steel. If, having secured a sufficiently ductile metal, we get, in addition, a high elastic limit, our gun must be stronger than if made of weaker material.

For the tube and jacket, the present system of gun construction exacts a more yielding metal, that all the layers of the gun wall may reach the elastic limit at the same time. Practically, the characteristics of the hoop dominate those of the tube and jacket. Given the strongest hoop compatible with absolute security, the tube and jacket steel must be graded down in accordance, so as to obtain the maximum value of the compound structure. Now, this gradation is secured by slightly varying the percentage of carbon coupled with oil-tempering and subsequent annealing. The latter process, which relieves internal strains and secures the necessary ductility, is not so much as alluded to by the writer.

Are we to understand that mild steel is not acted on by the process of oil-tempering? The behavior of the gun shields for the new cruisers, all of which are so treated, negatives such an inference, as does the case of the Cambria locomotive tire, which, after tempering and annealing, had 110,700 pounds tensile strength, 57,180 pounds elastic limit, 17½ per cent. elongation in 2½ inches and 47.2 per cent. reduction in area.* Would Mr. Dorsey hesitate to use such a tire on a locomotive?

I have here the record of the E-hoop of 8-inch B. L. R. No. 2. Its tensile strength is 85,816 pounds, its elastic limit is 34,887 pounds, its elongation is 29.55 per cent., and its reduction of area is 47.29 per cent. That is ductile enough, surely. It is indeed mild

* Report of the Chief of Ordnance, 1885.

steel. We temper and anneal it, raising its tensile strength to 104,659 pounds and its elastic limit to 54,748 pounds without unduly sacrificing the other characteristics. And yet we are to be condemned for increasing the elastic limit by over a half!

I am indebted to Mr. Davenport, the Superintendent of the Midvale Steel Works, for the following table illustrating the effect of oil-tempering and annealing on the mild steel used in our guns, adding that the mechanics at the Washington Navy Yard are unanimous as to its uniform quality.

*Tubes.*

| | Midvale Tests. Before Treatment. | | | | Washington Tests. After Treatment. | | |
|---|---|---|---|---|---|---|---|
| | Tensile Strength. | Extension. | Contraction. | Position of Test Piece. | Tensile Strength. | Extension. | Contraction. |
| No. 12. | | | | | | | |
| H. 5798 | 82,709 | 16.5 | 22.56 | M.T.C. | 79,387 | 23.95 | 48.37 |
| | | | | M.T.I. | 86,564 | 21.40 | 45.76 |
| | | | | B.T.C. | 82,430 | 24.80 | 43.10 |
| | | | | B.T.I. | 80,430 | 25.40 | 43.50 |
| | | | | B.L.C. | 79,640 | 25.90 | 59.30 |
| No. 21. | | | | | | | |
| H. 7142 | 74,722 | 18 | 23.61 | M.T.C. | 83,206 | 24.00 | 46.70 |
| | | | | M.T.I. | 86,920 | 22.00 | 43.70 |
| | | | | B.T.C. | 78,544 | 27.80 | 42.90 |
| | | | | B.T.I. | 78,870 | 22.70 | 49.40 |
| | | | | B.L.C. | 80,773 | 25.70 | 55.90 |
| No. 17. | | | | | | | |
| H. 7170 | 82,053 | 17 | 19.59 | M.T.C. | 87,913 | 21.90 | 46.16 |
| | | | | M.T.I. | 76,597 | 24.00 | 43.07 |
| | | | | B.T.C. | 82,807 | 25.20 | 45.83 |
| | | | | B.T.I. | 79,763 | 28.65 | 59.28 |
| | | | | B.L.C. | 76,690 | 29.55 | 53.39 |
| No. 16. | | | | | | | |
| H. 7171 | 76,129 | 16.5 | 25.30 | M.T.C. | 83,727 | 23.55 | 40.40 |
| | | | | M.T.I. | 82,301 | 26.65 | 48.70 |
| | | | | B.T.C. | 82,632 | 18.70 | 33.42 |
| | | | | B.T.I. | 87,503 | 25.00 | 49.52 |
| | | | | B.L.C. | 86,489 | 25.25 | 58.18 |
| No. 11. | | | *Jackets.* | | | | |
| H. 5423 | 89,555 | 11.5 | 16.83 | M.T.I. | 94,858 | 21.80 | 35.90 |
| | | | | M.T.C. | 98,523 | 18.40 | 31.33 |
| | | | | B.T.I. | 88,771 | 21.60 | 30.10 |
| | | | | B.T.C. | 91,641 | 19.30 | 40.20 |
| | | | | B.L.I. | 88,165 | 26.90 | 54.40 |
| | | | | B.L.C. | 87,122 | 26.80 | 55.40 |

*Jackets.*

| | Midvale Tests. Before Treatment. | | | | Washington Tests. After Treatment. | | |
|---|---|---|---|---|---|---|---|
| | Tensile Strength. | Extension. | Contraction. | Position of Test Piece. | Tensile Strength. | Extension. | Contraction. |
| No. 15. | | | | | | | |
| H. 6447 | 78,144 | 19 | 21.85 | M.T.C. | 90,547 | 23.01 | 45.70 |
| | | | | M.T.I. | 96,502 | 22.40 | 40.89 |
| | | | | B.T.C. | 85,138 | 19.25 | 28.48 |
| | | | | B.T.I. | 85,051 | 16.25 | 28.40 |
| | | | | B.L.C. | 86,809 | 23.00 | 48.70 |
| | | | | B.L.I. | 88,107 | 23.00 | 48.40 |
| No. 17. | | | | | | | |
| H. 7100 | 83,850 | 17 | 22.56 | M.T.C. | 102,157 | 20.65 | 40.82 |
| | | | | M.T.I. | 98,523 | 18.50 | 36.83 |
| | | | | B.T.C. | 95.744 | 19.95 | 39.65 |
| | | | | B.T.I. | 92,576 | 21.15 | 35.30 |
| | | | | B.L.C. | 94,249 | 27.65 | 51.48 |
| | | | | B.L.I. | 96,256 | 22.80 | 47.29 |
| No. 12. | | | | | | | |
| H. 5422 | 82,709 | 17 | 24.31 | M.T.I. | 92,460 | 21.45 | 37.47 |
| | | | | M.T.C. | 92,460 | 21.00 | 27.99 |
| | | | | B.T.I. | 89,528 | 22.60 | 40.53 |
| | | | | B.T.C. | 90,944 | 22.60 | 42.70 |
| | | | | B.L.I. | 87,913 | 26.50 | 53.20 |
| | | | | B.L.C. | 94,733 | 21.00 | 47.40 |
| | | | *Hoops.* | | | | |
| $A_2$ No. 16. | | | | | | | |
| H. 5681 | 79,538 | 15.5 | 22.86 | T.C. | 103,828 | 20.25 | 40.27 |
| | | | | T.I. | 107,112 | 18.50 | 40.58 |
| $A_1$ No. 11. | | | | | | | |
| H. 5688 | 81,811 | 23.5 | 37.52 | T.C. | 101,706 | 18.45 | 31.75 |
| | | | | T.I. | 105,025 | 15.20 | 27.26 |
| $A_2$ No. 19. | | | | | | | |
| H. 5692 | 97,539 | 17.00 | 26.72 | T.C. | 111,093 | 16.15 | 33.24 |
| | | | | T.I. | 115,149 | 16.40 | 37.86 |
| $A_4$ No. 15. | | | | | | | |
| H. 6387 | 100,559 | 15.00 | 29.72 | T.C. | 108,479 | 15.80 | 29.40 |
| | | | | T.I. | 106,607 | 17.10 | 34.90 |

There are three machine shops in this country where mild steel forgings of large size have been worked—at the Washington Navy Yard, at West Point, and at South Boston. I have yet to hear of one such mass cracking when completely at rest, as alleged by Mr. Dorsey. Nor are the failures of guns in England to be charged to the trustworthy product of the open hearth. Mr. Dorsey cannot quote a single failure of an English gun similar to ours in material.

Mr. Dorsey makes a good suggestion when he advises testing the value of oil-tempering on large masses. I am not disposed in this matter to throw the burden of proof on him, for guns, like some other things, must be beyond suspicion, although, strictly speaking, it is incumbent on him to establish his case.

I am particularly anxious to see this experiment tried, for the author explicitly admits that the tensile strength of mild steel may, by work, "be raised very high without impairing the quality." In other words, the tensile strength should not, alone, condemn the metal. Now, if oil-tempering a forging is not putting work either *on* it or *in* it, I should like to know what it is.

The quoted statement of the Duke of Cambridge has been made to do duty in many causes already, and I venture to predict for it a long life and a busy old age. When we remember that a gun is disabled through the breaking down of the carriage or the disarrangement of the breech mechanism, etc., as well as by absolute explosion, it becomes clear that what is needed is a detailed description of the damages sustained.

I really disapprove of hard steel as much as the author, although we may not (or may) draw the line of demarkation at the same point. Krupp used only crucible high steel, however, and what bearing the collapse of his guns, burning quick powder, has on the reputation of our Dolphin's gun, for example, with its fine record of 300 rounds, more or less, of brown powder, I am sure I do not know.

The gun steel we use is costly because it must be forged in larger masses than are common, not because its composition is expensive. The ingot, as cast, is no costlier than other ingots made from selected material. The tube cannot be eliminated, that is certain, and the jacket, or its equivalent, is necessary. Given the plant to produce them, and the hoops are really cheap. They must, however, practically bear their share of the burden equally with the tube and jacket.

I am glad that a champion has been found for good mild steel in this country, as against the cast-iron and cast-steel men; but, as has been pointed out by Professor Munroe, the author's own logic leads him to the wire gun. Now, gun wire is, by his own definition, high steel.

In conclusion, let me say that I think Mr. Dorsey has yet to show that the metal approved by all the great gunmakers of the world is untrustworthy; still, as affording us an opportunity of giving our reasons for the faith that is in us, which has produced so unusually

wide and interesting a discussion, as well as by warning us of a danger likely to be thrust upon us in the near future, he has earned our gratitude.

It is my pleasant task, before adjourning the meeting, to extend to the author the hearty thanks of the Newport Branch of the Naval Institute, as well as to express our sense of obligation to the distinguished gentlemen not members who have been kind enough to take such an active part in our discussion.

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*Submitted by* MR. E. BATES DORSEY, C. E.

In conclusion, I will give a few quotations from high authorities on steel. These show that others have my views—that open-hearth hard steel is not a safe material for constructing guns, especially large ones.

The report to the United States House of Representatives by the Randall Committee, in 1886, on "Ordnance and Warships," says: "The question of making gun steel, even in small masses, is a delicate and difficult operation." What is the necessity of this "difficult operation"? Why not make it of mild steel, which is a simple and cheap operation in any size masses?

The *Engineer* of London, a very high authority on engineering and mechanical matters, in a late number, in reference to the English steel guns bursting, says:

"The only way in which big guns can be made safe is to reject absolutely all steel which is too hard. The ordnance authorities show by the tests which they have laid down for gun steel that they do not yet fully understand what a soft steel is; or else that they have knowingly adopted a steel which is hard, for a reason which they have not stated. They say that gun steel must have a breaking stress of not less than thirty-five tons or more than forty-five tons. Now, this is flatly opposed to the practice not only of Lloyd's, but of all engineers. It is perfectly understood outside the War Office that a steel to stand tensile strains must, under no circumstances, have a greater tensile strength than thirty-two tons to the square inch, or no less than thirteen tons less than the War Office maximum, and three tons less than the War Office lowest limit. No engineer in his senses would think of making a boiler, or a bridge, or a tire, out of steel with a 45-ton limit; and we say without hesitation that if the War

Office will rest content to make its guns of steel with a minimum limit of thirty tons and a maximum of thirty-two tons, and an elongation of twenty per cent., there will be no more broken guns—always provided, of course, that the gun is properly proportioned to the nature of the powder to be burned in it.

"We have said that the authorities possibly adopt a hard steel for a special reason. This reason is that it is assumed—we are not aware that it has ever been proved—that soft steel scores so fast as soon to render a gun useless. Whether this is so or not, the true remedy does not lie in using hard steel; or rather the remedy is much worse than the disease. Unless soft, tough steel is employed in guns, the results must be disappointing. It is all very well to talk of oil-tempering and so on. Such treatment may mitigate the evil, it will not remove it. . . . . .

"In any case, if the use of hard steel is to be persisted in, then it must have the form of a comparatively thin tube, which can be taken out without much trouble in case of failure, and this tube must be covered from end to end with one, if not two, other tubes of soft steel. Knowing, however, as much as we do of steel, we repeat that the use of any steel with a higher tensile strength than thirty-two tons, or at the outside thirty-three tons, to the square inch, is a serious mistake, and so long as it is persisted in, so long shall we continue to hear of failures of guns; and it must not be forgotten that such failures need not all be of the Collingwood or Active type. We may have the chases split or cracked without the complete breaking up of the gun; and we shall not be wrong if we assert that the occurrence of failures of this kind is very far from uncommon. It is not confined to the guns of Great Britain—the guns of all nations are liable to fall victims. Hard steel is no respecter of persons or nations. Engineers know it to be a treacherous material; and artillerists will do well in this matter to profit by the experience which engineers have acquired with much trouble and vexation of mind and at an enormous expense."

This is a very emphatic endorsement of my views.

The *Engineering* of London, also very high authority on engineering and mechanical matters, in its edition of September 24, 1886, says in reference to the Collingwood accident: "In relation to guns, no further argument is needed to tell us that some better method than the one now in use must be found for the supply of the Army and Navy." In reference to the report of the committee appointed to investigate the cause of the bursting of the 12-inch gun on the

Collingwood, it says: "They find that the metal in the chase was irregular in its character, and as such it would be specially liable to the setting up of internal strains during the process of forging and oil-hardening." This is a very true definition of the character of all open-hearth hard steel.

In its issue of October 1, 1886, in reference to "Big Guns," it says: "More than this, our War Office is not even in possession of designs that combine efficient material with simplicity of form and economy of manufacture." *Engineering* thinks that the plans of the English War Office are incorrect and unsafe. It advocates thorough experiments in the following strong language: "But this question cannot be decided on paper, nor by discussion. It is only by experiment such as we have proposed that practical results can be obtained. The sooner we commence, and the more comprehensive we make them, the earlier will come our feeling of security."

These extracts from the two leading mechanical and engineering papers of England show that, notwithstanding their long experience and heavy outlay in money, the gun question is still unsettled, and they must experiment in order to find out the best gun and material to adopt. The opinions seem to be very decided against the use of hard steel.

The *American Manufacturer and Iron World*, good authority on iron and steel, in its edition of December 3, 1886, in reference to guns, says: "The time has finally come when our Government should abandon definitely and forever its costly experiments with 'built-up' guns made on the absurd and unscientific European system now in vogue. The evidence of the absolute non-reliability of guns made on this system, even by the best makers, is overwhelming. The English Ordnance Board report, concerning the bursting of the Collingwood's 43-ton gun, that this gun 'would be specially liable to the setting up of internal strains during the processes of forging or of oil-hardening.' Relative to the *material* in the Krupp guns, Col. Hennebert says: 'During the war of Bohemia several fieldpieces burst. After the war, in order to allay public agitation, trials *à outrance* were made, and these cost several young officers their lives. In 1868, General de Bœuf declared that several guns firing ordinary charges had burst; nor can it be said that the Prussian steel guns of to-day are safe. In fact, between 1867 and 1870 numerous accidents occurred in Russia, England, Germany, and Italy, on land and on board ship.' Colonel Hennebert says that during the Franco-German

war 200 Krupp guns burst, as mentioned by Major Haig in a report read before the Royal Artillery Institution, and by the Duke of Cambridge in a speech in the House of Lords on April 30, 1876: 'Out of seventy heavy guns employed against the southwest of Paris, thirty-six were disabled during the first fortnight of the bombardment by the effect of their own fire. At Versailles it was thought that if the French had held out a week longer, the German siege batteries would have been reduced to silence. It is evidently certain that during the campaign on the Loire, Prince Frederick Charles had twenty-four of his guns disabled by their own fire.'

"This is what might have been expected. Every steelmaker who is not a gunmaker says these large masses cannot be forged so as to be safe from injurious strains.

"Every mechanic who is worthy of the name knows that such masses of rings and tubes cannot be fitted and assembled so as to act as a continuous whole, and even if they were so fitted they could not be retained in that condition after the warming up of the first few rounds."

The *Engineering and Mining Journal* of New York, one of the highest metallurgical authorities, in a recent number says:

"IS HARD STEEL SUITABLE FOR HEAVY GUNS?

"The question of hard or soft steel in cannon has for some time attracted the attention of engineers, especially since the recent bursting of some of the English naval guns, although the experience of Germany and France in the Franco-German war had already demonstrated a very large proportion of failures among guns made of this metal.

"Since the very introduction of steel for structural purposes, engineers have found it necessary to use only low-carbon or mild steel; for it was early found that hard steel was brittle and incapable of resisting shocks. Take, for example, such uses as for shipbuilding, for bridges, for locomotive tires, for roll shells in crushing ore, for jaw-plates in rock-breakers, and generally for uses where sudden and heavy blows or vibrations are to be expected.

"It is true we yet know very little concerning the reasons why hard steel, capable of resisting extremely high tensile strains, should break under comparatively light shocks; but the fact is perfectly recognized, nevertheless, and in all works where the contractor is held by business interest or direct specification to secure a durable structure of steel,

he would not think of adopting the hard metal. It seems incomprehensible, therefore, that in guns, where the jar and vibration are probably greater than in any other engineering use, Government engineers should have adopted a metal that has long been condemned and rejected by civil engineers in all uses where the conditions are analogous."

The *Engineering News and Contract Journal* of New York, which deservedly stands very high as an engineering journal, in reference to guns, says in a recent issue:

"Many prominent engineers and steel-workers agree with the author that hard steel, made by the open-hearth process, and as called for in the specifications of the U. S. Ordnance Bureau of the Army and Navy, cannot be considered a safe material for heavy guns; at least with our present knowledge of its properties. In fact, we consider this material utterly unreliable when used in the great masses called for by the size of modern guns; and in this we are supported by some of the best engineering authorities in the countries where guns so made have already been tested and practically found wanting.

"A material rejected by bridgebuilders and boilermakers because of its unreliability under sudden stress, is certainly not the stuff to put into guns that are supposed to successfully resist the most abrupt and violent of shocks to which the materials of construction could possibly be subjected."

The preceding extracts from the leading engineering and mechanical papers of England and the United States are very decided against the use of hard steel for constructing guns.

In the early days of steel, and before mild steel was commercially known, small guns were made from hard steel and found to answer well. Since then the size of guns has very largely increased, and ordnance-makers have continued to use the same material for the construction of the large as they did for the construction of the small guns, ignoring entirely the discovery of mild steel—a much more reliable and cheaper material. They also seem to have overlooked the fact that the difficulty and cost of working and forging hard steel are increased very rapidly with the size.

It is not fair to blame our ordnance officers for this, as they have been so stinted in appropriations that they have not been able to experiment for themselves, and in the absence of these experiments they were obliged to adopt the practice of foreign countries—especially

England. The English adopted a certain class of steel for small guns twenty-five years ago, and with their usual conservatism they have adhered to it up to the present time, making from it alike large and small guns.

Civil engineers made the same mistake, using hard steel at the commencement with high tensile strength, but by the failure of their work they soon learned to use mild steel—about two-thirds of the tensile strength they used at first.

Congress should give our ordnance officers ample means to make their own experiments and tests, and not oblige them to follow the practice of foreign countries.

In order to settle knowingly the gun question, a commission should be appointed consisting of Army and Navy officers and civil engineers, Congress giving them ample power and means to buy for experimenting purposes the best make of guns, both foreign and domestic, including cast-iron and cast-steel. Let these be equally subjected to the same severe fire of small guns and machine guns as they would be in actual service. After this test them to destruction, giving to each the same amount of good and bad treatment. "The survival of the fittest" will show us the type and model we must adopt for our guns.

This commission, composed as above stated, would have the united knowledge and experience of the three professions.

These experiments, in order to be thorough and complete, must necessarily be very expensive; but it will be money well spent, as it will be the means of giving us good and serviceable guns. Otherwise, by our present policy, we will spend several hundred millions of dollars on guns that may be found useless in the hour of trial; probably many doing more harm to our officers and men than to the enemy.

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DECEMBER, 1886. The velocity of light in air and refracting media, by Professor Albert A. Michelson.

COMPETITIVE TRIALS OF CHRONOMETERS 1884 AND 1886.

Appendix III of the Washington Observations for 1883, recently issued, contains a collection of papers embracing a description of the temperature-room used at the Naval Observatory for chronometer-testing, and an account of the competitive trials of chronometers in 1884 and 1886. The Appendix is in the shape of a report of the Superintendent, Allan D. Brown, U. S. N., to the Chief of the Bureau of Navigation.

The first part is a reprint of the paper by Lieutenant E. K. Moore, U. S. N., entitled "Method of Testing Chronometers at the U. S. N. Observatory," originally published in the *Institute Proceedings*, Vol. X, No. 2. Next follows a reprint of "Competitive Trials of Chronometers at the U. S. N. Observatory," by the same author, *Proc. U. S. N. Inst.*, Vol. XI, No. 1. The new matter includes a paper by Lieutenant E. C. Pendleton, U. S. N., who describes the last competitive trial, and a description of changes in the arrangement of the temperature-room by Commander Brown, with a plate showing the ingenious construction of the gas-tight automatic valve through which the fuel (gas) for heating is supplied and cut off.

The Appendix presents in a compact form the present state of knowledge regarding the effect of both temperature and humidity on the chronometer, as well as the steps in the investigation of these influences at the Naval Observatory.

As such it is an interesting and valuable contribution to the literature of the subject.

A few points may be briefly referred to:

It is a subject for congratulation that the art of chronometer-making has so

advanced in our country that the restriction can be imposed that no chronometers but those of American manufacture shall be admitted to these competitive trials, and that the makers are willing and anxious to compete.

The work of the officers having charge of the chronometers at the Naval Observatory has proved incidentally that research is well expended in the attempt to improve our present instruments of navigation, and that such research affords a field where the scientific attainments of our officers can well and profitably be employed. The work of the authors of the above papers is in worthy succession to the previous labors of Lieussou, Hartnup, Davis, and of other investigators.

As is well known, the influence of a varying temperature on a carefully kept chronometer has an effect greater than that of any other influence. This effect having become measurable by the refined processes of the Observatory, the effect of a varying humidity has also been studied.

The impression is prevalent that chronometers follow a fixed law with a variation of the humidity. The last trial of chronometers, however, proves that no hard-and-fast rule can be laid down, some chronometers gaining while the humidity was increased, others losing. "The only thing that can be said, then, of each of these individual instruments is that with an increase of humidity it will *probably* gain or lose, as shown by this test." Even such a statement, it is plain, must be vastly superior to a general assertion, as sometimes seen in print, that chronometers will gain on their rate when the humidity decreases, and lose when it increases.

In this connection it will be found interesting to consider the remarks on the effect of a humidity short of saturation contained in the report of the Superintendent for the year ending June 30, 1886, page 7. As an additional safeguard against chronometers rusting, it is suggested that "each chronometer be supplied with a baize cover, to be kept on it at all times when the instrument is not in use; a second one should be provided, and in wet weather the cover should be changed daily and dried at the galley." A. G. W.

## ENGINEER.

### NOVEMBER 5, 1886. Particulars of armored vessels.

| | Immortalité. | Mersey. | Hero. | Benbow. |
|---|---|---|---|---|
| Length between perpendiculars | 300 feet. | 300 feet. | 270 feet. | 330 feet. |
| Breadth (extreme) | 56 feet. | 46 feet. | 58 feet. | 68 feet 6 inches. |
| Displacement | 5000 tons. | 3350 tons. | 6200 tons. | 10,000 tons. |
| Engine | Horizontal direct-acting. | Vertical direct-acting. | Horizontal direct-acting. | Inverted direct-acting. |
| Horse power | 8500. | 6000. | 6000. | 7500. |
| Size of cylinders | 36-inch H. P.<br>51-inch intermediate.<br>78-inch L. P. | 38-inch H. P.<br>64-inch L. P. | 42-inch H. P.<br>84-inch L. P. | 52-inch H. P.<br>74-inch L. P. |
| Stroke | 3 feet 6 inches | 3 feet 3 inches. | 3 feet. | 3 feet 9 inches. |
| Boilers, heating surface | 15,472 square ft. | 11,771 square ft. | 14,224 square ft. | 20,244 square ft. |
| Grate surface | 488 square feet. | 399 square feet. | 507 square feet. | 800 square feet. |
| Pressure | 130 pounds. | 110 pounds. | 84.5 pounds. | 90 pounds. |
| | Armament. | Armament. | Armament. | Armament. |
| | Guns: 9 2-in. B. L. No. 2; 6-in. 89-cwt. B.L. No. 10. | Guns: 8-in. B.L. No. 2; 6-in. 81-cwt. B. L. No. 10. | Guns: 12-in. 43-ton B. L. No. 2; 6-in. 89-cwt. B. L. No. 4. | Guns: 110-ton B. L. No. 2; 6-in. 89-cwt. B.L. No. 10. |
| | Also to be fitted with quick-firing and machine guns and Whitehead torpedoes. | Also to be fitted with quick-firing and machine guns and Whitehead torpedoes. | Also to be fitted with quick-firing and machine guns and Whitehead torpedoes. | Also to be fitted with quick-firing and machine guns and Whitehead torpedoes. |

NOVEMBER 19. Editorial calling attention to the great and unaccountable condensation of steam in the H. P. cylinder and jacket of compound engines.

In one case it appeared that 13 square feet of steam cylinder was as efficient for condensing purposes as two square feet of small tubes immersed in water, and that one square foot of jacket was about equal to five or six square feet of condenser tubing.

DECEMBER 3. On the manufacture and use of wrought-iron castings.

Good wrought-iron scrap is melted in a petroleum furnace in crucibles, and when just fluid .05 or .1 of one per cent. of aluminum is added. This lowers the melting-point about 400°, gives fluidity sufficient for casting, and at some time liberates gases previously absorbed. The product is uniform in quality and equal to the best wrought iron; can be welded and forged; the tensile strength is twenty to fifty per cent. greater than that of the raw material.

DECEMBER 10, 1886. Particulars of a trial of torpedo boat No. 79, the speed of which surpassed that attained by any other similar craft in the English service.

Length of boat, 125 feet; beam, 13 feet; mean draught, 3 feet 4 inches; load carried, 10 tons. Turning circles, going ahead: to port, 80 yards diameter in 59 seconds; to starboard, 90 yards diameter in 57 seconds. Going astern: starboard, 70 yards diameter in 70 seconds; to port, 60 yards diameter in 60 seconds. Vibration, practically none.

| Steam. | Receiver. | Vacuum. | Revolutions per minute. | Time. | Speed. |
|---|---|---|---|---|---|
| Lbs. | Lbs. | Ins. | | H. M. | Knots. |
| 139 | 59 | 26 | 411 | 2 42 | 22.22 |
| 139 | 60 | 26 | 410 | 2 31 | 23.84 |
| 140 | 60 | 26 | 400 | 2 32 | 23.68 |
| 140 | 60 | 26 | 398 | 2 54 | 20.68 |
| 140 | 60 | 26 | 404 | 2 30 | 24.00 |
| 140 | 62 | 26 | 403 | 2 52 | 20.93 |
| 140 | 62 | 26 | 401 | 2 30 | 24.00 |
| 140 | 62 | 26 | 401 | 2 53 | 20.80 |

[*Note.*—Mean of last six runs made over measured mile alternately with and against the tide is 22.39 knots.] W. F. W.

DECEMBER 17, 1886. Trial of the Spanish twin-screw torpedo cruiser Destructor.

Displacement of vessel, 350 tons; total I. H. P. of both engines, 4000; mean speed for four consecutive hours, 22.65 K.; mean speed for four consecutive hours in heavy sea-way, 22 K.; revolutions per minute, 350; coal supply sufficient to steam 700 K. full speed; coal supply sufficient to steam 5100 K. at 11½ K. The four boilers, of locomotive type, worked without priming or leaking, with forced draught of two inches. The time required to turn a complete circle less than three times the ship's length was one and three-quarter minutes. W. F. W.

*Table Showing the Relative Efficiency of Different Types of Engines.*

[Taken from "Die Schiffsmaschine."]

| Type of Engine. | Most advantageous number of times to expand the steam. | Pounds of coal required per hour per I. H. P. when working most economically. | Pounds of water required per hour per I. H. P. when working most economically. | Relative efficiency of the different types of engine, each cutting off at its most economical point. |
|---|---|---|---|---|
| 1. Newest compound engines with great piston speed and high steam pressure. [Date of publication of the data 1883] | 10 | 1.8 to 2.2 | 18 to 21 | 40 |
| 2. Older compound engines with lower piston speed and lower steam pressure | 6⅔ | 2.2 to 2.6 | 21 to 25 | 36 |
| 3. Compound engines working with 60 pounds steam pressure, surface condensers, steam jacket, and superheated steam | 4 | 2.6 to 3.1 | 25 to 29 | 30 |
| 4. Simple engines with 45 pounds steam pressure, surface condensers, steam jacket, and superheated steam. | 2⅘ | 3.1 to 3.5 | 27 to 31 | 26 |
| 5. Simple engines with jet condensers, without steam jacket and without superheated steam | 2½ | 3.5 to 4.4 | 31 to 36 | 24 |
| 6. Old simple engines with less than 45 pounds steam pressure, with jet condenser, and without steam jacket or superheated steam | 1⅔ | 4.4 to 5.5 | 36 to 40 | 20 |

ENGINEERING.

November 19. Article on the German Navy from a Spanish official document giving the plan of organization, description of ships and torpedo boats and system of coast defenses, etc.

December 17, 1886. Particulars of H. M. S. Narcissus, just launched.

Length, 300 feet; beam, fifty-six feet; draught, twenty-one feet; expected speed, nineteen knots. Steel-faced armor belt ten inches thick, backed with 6-inch teak; two hundred feet long, extending one foot six inches above to four feet below water-line. On level with top of this is the protective deck of 2-inch steel in wake of armor, and three inches thick, inclined at 30° towards ends of ship outside of belt. Conning tower has 12-inch steel-faced armor. Armament, one 10-inch breechloader in citadel, with ten 6-inch guns. Between decks are ten Hotchkiss and two 9-pounders. There will be two jury masts with fighting tops. Engines, horizontal, direct-acting, triple-expansion; diameters of cylinders, thirty-six inches, fifty-one inches and seventy-eight inches; stroke, forty-two inches; condensers of brass with 12,000 square feet cooling surface; pumps and connections, gun metal; two double-ended steel boilers fourteen feet six inches diameter by seventeen feet six inches long, with corrugated furnaces; pressure, 130 pounds; propellers of gun metal fourteen feet six inches diameter. W. F. W.

GIORNALE D'ARTIGLIERIA E GENIO.

No. 8, 1886. Inspection and proof of gunpowder, with plates.

INSTITUTION OF MECHANICAL ENGINEERS, LONDON.

No. 3. Experiments on steam-jacketing and compounding of locomotives in Russia, by Mr. Alexander Boradin. On the working of compound locomotives in India, by Mr. Charles Laniford.

JOURNAL DU MATELOT.

No. 42.

The Dupuy-de-Lome has been commenced at Brest, and the Jean Bart at Rochefort. They are steel cruisers of the first class, with barbette towers, after the plans of M. Thibaudier. The principal characteristics are: Water-line length, three hundred and fifty-three feet three inches; beam, forty-three feet eight inches; depth, thirty feet six inches; least draught, eighteen feet nine inches; displacement, 4162 tons; speed, nineteen knots. Armed with four 16-cm. and six 14-cm. guns, six revolving cannon 37 mm., four rapid-fire guns 47 mm., and four tubes for torpedoes. The engines, boilers and other vulnerable parts are protected by a steel shield.

No. 46. "Maritime Experiments for 1886," a book published by Berger, Levrault & Co.

Its contents are: First experiment against the Protectrice with a submerged torpedo. Experiments in the Mediterranean with a fleet of ironclads and a fleet of torpedo boats, comprising all sorts of manœuvres; as, the bombardment of Toulon, defended by torpedo boats: the attack fell through, the blockade being forced, although there were eight ironclads. The passage of Cape Corsica effected, although with much loss to the ironclads, and the passage could have been prevented with a sufficient number of torpedo boats. Torpedo boats forced their way into Ajaccio, notwithstanding very bad weather, and spread disorder amongst the ironclads. Finally a squadron from Africa tried to force a passage through the Balearic Islands, but a small number of torpedo boats (after being at sea several days) did the squadron much harm. All this going to show that the torpedo boat is a terrible engine and will play an important part in future wars. D. H. M.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

JUNE 18, 1886. On the use of petroleum as fuel in steamships, etc.

The following information is obtained from a paper read and the subsequent discussion: The fuel used in Russia is a product of petroleum called "astatki," obtained by distilling the crude oil in iron boilers. The first products are benzine and gasoline, then kerosene and solar oil; all oil between .78 and .86 specific gravity being considered kerosene. This is a much higher specific gravity than American oil. The oil of specific gravity .86 to .88 is called solar oil. The remainder is called astatki, having generally the specific gravity .91 and higher. The burning-point of this is about 422°F. The astatki is injected into the furnace with a jet of steam or air, and its use is perfectly practicable. The number of vessels, including small tugs and steam launches, which use it on the Volga and Caspian Sea is estimated at not less than 200. Some of these have been using it for the last fifteen years. One of them has made 250 voyages. There are also a few steamers on the Black Sea using astatki, and two or three building in England to carry petroleum as freight will also burn it as fuel. Moreover, astatki is used at all the factories at Baku (about 100),

numerous factories on the Volga, some at Moscow and one at St. Petersburg, and more than 500 locomotives.

Comparing astatki with coal, the former has theoretical evaporative power of 16.2 pounds of water per pound of fuel, and the latter 12.2 pounds at 120 pounds steam pressure; hence astatki has, weight for weight, thirty-three per cent. higher evaporative value than anthracite. In locomotive practice a mean evaporation of seven to seven and a half pounds of water per pound anthracite is about what is generally obtained, thus giving in the case of coal about sixty per cent. efficiency, but with astatki an evaporation of 12.25 pounds is practically obtained, giving seventy-five per cent. efficiency. Weight for weight, the value of astatki is reckoned at $\frac{12.25-7.50}{7.5}=63$ per cent. to $\frac{12.25-7}{7}=.75$ per cent. higher than coal; that is, one ton of astatki is equal in practical efficiency for steam-generating purposes to about one and three-quarter tons of the best anthracite when the steam jet is used, and better results are obtained with air. The advantages in its use are:

(1) The stowage space for equal weights is less than coal in ratio of 38 to 45.

(2) It can be stowed in places not available for coal (between inner skin, etc.).

(3) Can be pumped on board at rate of 100 tons per hour and even faster.

(4) There is no ash, refuse or smoke.

(5) It requires no stoking or attention. Russian steamers on the Caspian run from port to port without attention to fires, and on these steamers only men enough are employed to keep the machinery clean.

(6) It can be supplied to furnaces from the bunkers with much greater facility than coal.

(7) It can be taken aboard from another steamer at sea.

With regard to cost. The price of astatki at present at Baku (on the Caspian Sea) is 2s. 6d. per ton. At Batoum (on the Black Sea) it is about 25s. per ton, which will probably be reduced to 17s. when the contemplated pipe line is finished. The cost of crude petroleum at Philadelphia (U. S.) is about 74s. per ton. The quantity of refuse fit for burning produced at Baku is very much greater in proportion to the crude oil than it is in America. In the United States about seventy per cent. of kerosene is obtained, while at Baku only thirty per cent., leaving a residue of seventy per cent. for fuel. Also, in the United States the residue is used for the production of anthracene, naphthalene and benzol, still further reducing the quantity available for fuel. W. F. W.

*Note.*—Mr. Martell, of Lloyd's, in course of the discussion, gives the cost of the best coal in England as eight shillings or ten shillings per ton, and freight to Batoum about fifteen shillings. This would make the cost of the best English coal in Batoum about twenty-three to twenty-five shillings per ton. Also, it appears that there are only a few steamers on the Black Sea using astatki at the *same price* (twenty-five shillings per ton), with the prospect of that price being soon reduced to seventeen shillings. Hence we may infer that the other advantages of astatki over coal are not so great or so obvious as the statements given in the paper and discussion would lead us to believe. It is to be noted that the cost of crude petroleum quoted in the discussion, and often used as the basis of an argument against the use of petroleum, is not relevant to the question, because, on the one hand, the crude oil cannot be safely stowed on a ship, and, on the other hand, no idea can be formed of the value of the by-products by simply considering the cost of the crude material. By distillation the products obtained in Pennsylvania are about as follows: Naphthas, sixteen and one-half per cent.; kerosene, seventy per cent.; loss, eleven and one-half per cent.; residue, two per cent. The naphthas are too explosive to be stowed with safety. The average wholesale price of kerosene for the year

1886, the lowest ever reached, was 7.07 cents per gallon, or $24.75 per ton of 2240 pounds (see Annual Statement New York Shipping and Commercial List, 1886). Hence this is excluded by cost. It only remains to inquire about the two per cent. residue. In order to obtain trustworthy information on this point, a letter was addressed by me to the Secretary of the Standard Oil Company, New York, and referred by him to the Pratt Manufacturing Company, New York, who kindly furnished the required information. The specific questions asked were: "1st. Can you produce a by-product from petroleum similar to the Russian astatki, and which you can sell for about $5.00 per ton? 2d. Could you supply that product in quantities of, say, 1000 tons per annum?" The answer was: "*We produce nothing from petroleum but what has a greater value than the price you name.* Some of the smaller manufacturing establisments about New York use by-products of petroleum as fuel for special reasons, entirely outside of economy. The current price of these products is from three to three and one-half cents per gallon (*i. e.* $10 to $12 per ton)." W. F. W.

MECHANICAL ENGINEER.

NOVEMBER 27, 1886. Side elevation of engines of the 1700-ton new United States gunboat, with description. Table showing the evaporative power of pea, egg, and soft coal, and that the first is much the best for steam boilers, taking into account its present market value. Table of fifty-five steamships plying between New York and European ports, showing their tonnage and principal dimensions.

DECEMBER 11. Sketch and description of piston valves of new cruisers. W. F. W.

PROCEEDINGS OF THE CANADIAN INSTITUTE, TORONTO.

NOVEMBER, 1886. The archæological outlook. Classical notes. The law of habit. Rent—a criticism. The village community in modern politics. New England Upper Silurian. Etruria capta. Hypnotism. Mechanical value of coal. Analogy between consonants and musical instruments. The Eskimo of Stupart Bay. Gneissic foliation. Savagery in civilization. The mound builders in Canada. Aërial navigation. The last paper was an exhaustive treatise on the history of ballooning, by Alan Macdougall, M. I. C. E., F. R. S. E. The conclusion was that, so far as any success had been attained, it was more in the scientific than in the commercial solution of the problem. The number of lives which have been lost of late years is not compensated by any progress made in the practical solution of aërial navigation. P. F. H.

PROCEEDINGS OF THE SOCIÉTÉ DES INGÉNIEURS CIVILS.

JANUARY, 1886. Proposed plans of a bridge across the Douro River at Oporto.

FEBRUARY, 1886. Mathematical study of the action of propellers upon the water, and their construction. Use of compound engines on steamships, and reasons why multiple expansion cannot be advantageously used above certain limits.

MARCH, 1886. Comparative strength of iron and steel.

APRIL, 1886. Description of locomotive engine constructed by Bontel et Cie., of Paris, designed for a speed of sixty or seventy miles an hour.

MAY, 1886. Mathematical papers on the calculation of dimensions of machinery capable of producing currents of given strength and electro-motive force, and on the distribution of energy in dynamo-electric machines. Plans proposed for improving the channel at the mouth of the Seine and of the harbor of Havre.

JUNE, 1886.

JULY, 1886. Additional plans for improving channel at the mouth of the Seine.

AUGUST, 1886. S. M.

RÉUNION DES OFFICIERS.

No. 42. OCTOBER 16, 1886. Recruiting for the Navy. Law of July 22, 1886.

No. 44. OCTOBER 30, 1886. The three classes of torpedo boats. Estimates for construction of new vessels, 140 millions of francs, with 60 millions for other expenses not less necessary, such as different navy yards, ports of refuge and concentration; submitted by the Minister of the French Navy. A new cooking-apparatus for the Army.

No. 46. NOVEMBER 13, 1886. An article on experiments with the repeating rifle. Vitali's system as used in Italy.

No. 47. NOVEMBER 20, 1886. An interesting article on military roads, containing a map of Paris and environs, showing the railroads, stations, etc.; also the plan for a great union depot to be erected near the Trocadero. An article on repeating rifles; experiments carried on in Austria with the Mannlicher system; in Belgium with the Remington-Lee system, which has excited much interest in Belgium.

No. 48. NOVEMBER 27, 1886. Experiments with repeating rifles in Italy with Vitali's system, which has been adopted to the exclusion of all others.

In Portugal the rifle manufactured by Steyr, of Austria, has been adopted; the system is that of Kropatchek; 40,000 have been ordered. In this article there is much good reading as to the repeating rifle treated as an arm for attack and for defense. Also, an interesting article on cavalry raids, citing Stuart's famous raid into Pennsylvania. The *Bulletin de la Réunion des Officiers* ceased to exist with this number, and on December 4, 1886, was published, in its stead, the first number of the *Revue du Cercle Militaire, Armées de Terre et de Mer*. D. H. M.

REVUE DU CERCLE MILITAIRE.

No. 1. DECEMBER 4, 1886. An article comparing the power of artillery as against infantry. Also, The next Franco-Prussian war, by Colonel Von Kätschau.

No. 2. DECEMBER 11, 1886. Ending of article on Artillery *versus* Infantry. Continuation of Colonel Von Kätschau's article.

No. 3. DECEMBER 18, 1886. End of Colonel Von Kätschau's article. The organization of columns of attack, looking to the destruction of obstacles accumulated by the defending party. The special military school at Saint Cyr (1808 to 1812). D. H. M.

REVUE MARITIME ET COLONIALE.

NOVEMBER, 1886. The budget of the French Navy. The Legion of Honor. Determination of submarine currents. The advantages of the electric light for the interior of vessels. Filters acting by ascension. Reconstruction of the Navy of the United States.

DECEMBER, 1886. Elementary theory of the movement of the top, and its application to the artificial horizon. The gyroscope-collimator. Substitution of an artificial mark for the sea horizon. The budget of the English Navy. Naval Chronicle. English Navy: The Impérieuse, the Forth, the Tartar; trial of the Benbow. Russian Navy: The first-class cruiser Rynda. Swedish Navy: The iron-clad Svea. Artillery: The Hope cannon; the Firminez shell; the new explosive, Silotvaar; the new rubber composition sheathing called Woodite, from the name of the inventor, Mr. A. M. Wood. Torpedo vessels: The Brennan torpedo. An official trial of the Brennan torpedo took place at Sheerness on October 26, 1886. Torpedo boat No. 69, having a small target in tow, was started from Sheerness at full speed, and the torpedo was discharged from Garrison Point by Mr. Brennan himself against the target. This was struck while being dragged at the rate of sixteen knots an hour. The Brennan torpedo is from six to nine metres long and weighs about a ton. It is completely under the control of the operator on shore. At night its course is indicated by a small light produced by chemical action, and having a screen in front. It is said that this torpedo has been adopted for the defense of the English coasts. The inventor is an Australian. B. F. T.

RIVISTA DI ARTIGLIERIA E GENIO.

OCTOBER, 1886. The attack and defense of fortified places (conclusion). Cannon of manganese bronze. R. C. S.

RIVISTA MARITTIMA.

OCTOBER, 1886. The Italian merchant marine (conclusion). General index for the years 1868–1885 inclusive. Rome, 1886.

OCTOBER, 1886. The Volta, boat propelled by electricity.

On the 12th September this boat made the trip from Dover to Calais. It is of steel, thirty-seven feet long, six feet ten inches beam, and has a storage battery of sixty-one cells, and two Reckenzann electric motors, which act on the same shaft. By moving a crank the boat can be made to go at slow, medium, or full speed, or can be stopped or started without touching the storage battery. By another crank the motion of the machine is reversed by simply changing the direction of the current in the armature. The motors are placed in the stern

directly over the keel, and occupy a space of three feet ten inches long, one foot nine inches wide, and twelve and a half inches high. They weigh 730 pounds, and develop a maximum horse power of sixteen at the crank. The propeller is three-bladed, twenty inches diameter, eleven inches pitch, connected directly with shaft of motor. It makes at minimum velocity about 600 revolutions per minute, and at maximum velocity about 1000.

The storage battery weighs about two tons, and is placed along the keel under a wooden deck. On the day of the trial the cells were charged by means of a dynamo on shore at Dover. The E. M. F. at the start was 120 volts at twenty-eight ampères. The boat left the quay at Dover at 10.41 A. M. and reached Calais at 2.32 P. M., thus requiring three hours and fifty-one minutes for the trip; but it did not pursue a direct course. The trip was made at reduced speed (about 600 revolutions per minute), to economize the current to make sure of being able to return. On being tested at Calais, the battery measured twenty-eight ampères, as at the start. During the passage the boat moved smoothly and quietly, with a speed of about seven miles per hour. On the return, which was also made at reduced speed, the boat left Calais at 3.14 P. M. and reached Dover at 7.37, requiring four hours and twenty-three minutes. The current remained constant at twenty-eight ampères until 5 P. M., but at 6 P. M. it had fallen to twenty-five, and on arrival at Dover it was twenty-four. Nevertheless, on approaching Dover there remained sufficient motive power so that the last half mile was run at full speed (1000 revolutions), and the speed of the boat was about fourteen miles per hour. W. F. W.

## UNITED SERVICE GAZETTE.

OCTOBER 23, 1886. Is England ready for war? a paper embodying the substance of a memorandum which has recently been presented to the Board of Admiralty, by Lord Charles Beresford, Junior Lord of the Admiralty.

The Forth, second-class steel steam cruiser with twin screws, was launched at Pembroke, October 23. She is a vessel of 3550 tons, 5700 horse power, and will carry twelve guns. Her keel was laid down December 1, 1884.

OCTOBER 30. Coaling stations.

The Lords of the Admiralty, with the view of encouraging scientific study at the Royal Naval College, have been pleased to sanction the following prizes, which are to be awarded at the close of each session—viz.: One prize of £100 for general proficiency; two prizes of £80 each for gunnery and torpedo lieutenants gaining the highest marks in their respective courses.

NOVEMBER 13. The late Admiral Hobart Pasha. The Chatham dockyard. Establishment of the "Distinguished Service Order" by the Queen.

NOVEMBER 20. Abstract of French naval estimates.

Count Bylandt, Austro-Hungarian Imperial Minister, has announced that the Mannlicher repeating rifle of eleven millimetres radius of barrel, and firing eighty shots a minute, will be adopted.

NOVEMBER 27. The Royal Naval Artillery Volunteers. Abstract of memorial accompanying German naval estimates.

With a view of training seamen in the management of torpedo boats, directions have been issued by the Admiralty for No. 4 torpedo vessel to be attached to the Medway Steam Reserve for instructional purposes.

DECEMBER 4. Lord Brassey on the Navy.

The gunboat built at La Seyne, which has attracted so much attention in France, has the following dimensions: Total length, 41 metres; beam, 3.8 metres; weight of hull, 26.8 tons; weight of motive machinery (compound 560 horse power), 22 tons; weight of gun and carriage, 11.5 tons. The vessel is divided into nine water-tight compartments, and at her trials attained a mean speed of 19.2 knots. She has the shape of a torpedo boat, possesses great nautical qualities, is swift and almost invisible, and is built with great strength in order to withstand the discharge of the 14-centimetre gun which forms her only armament. This piece is protected by a steel-plate screen against an enemy's projectiles. The vessel cost $53,000.

Trial of a new submarine boat.

DECEMBER 11. Mr. Forwood's remarks about the English Navy. The Royal Military Academy at Woolwich.

On Tuesday, December 7, at Spithead, H. M. S. Edinburgh made a trial of her four 45-ton breechloading guns. Considerable interest attaches to the testing of these 45-ton guns, which have superseded the old 43-ton pattern, the Collingwood explosion having proved them to be too weak at the chase and necessitating them being hooped to the muzzle. Six charges were fired from each 45-ton gun with satisfactory results.

DECEMBER 18. Gunboat Warfare, by Admiral Sir George Elliot, R. N. Quick-firing guns in field operations.

The trial of the new hydraulic gun-mounting for the 68-ton 13.5-inch Woolwich guns which are to be mounted in the barbette ships of the Admiral class commenced on board the Handy, off Shoeburyness, December 13, under the direction of Captain Dornville and the officers of the Excellent. The programme consisted of a scaling charge and twenty rounds, of which eight were with a reduced charge of 423¾ pounds of brown powder, and twelve with the full charge of 565 pounds (the largest charge ever fired in a naval gun in England, being nearly twice the full charge of the 45-ton guns), the projectile in each case weighing 1250 pounds. Owing to misty weather, only four rounds were fired on the 13th, but the remaining sixteen rounds were concluded on the following day, the hydraulic mounting and breech mechanism behaving to the complete satisfaction of the officers present.

DECEMBER 25. The Fleet, poem by Lord Tennyson. The coming war.

On Monday, December 20, Lord George Hamilton, First Lord of the Admiralty, Captain Fisher, Director of Naval Ordnance, and other officials connected with the Admiralty, made a trip in the new torpedo boat No. 79, which has just been completed by Messrs. Yarrow & Co. Special interest attaches to this boat, owing to the fact that it is not only the fastest vessel in the British Navy, but is also the most rapid in manœuvring. At the official trial the speed attained during a two hours' continuous run was 22.4 knots per hour, and when going ahead the boat is capable of being turned in a circle the radius of which is about equal to her length. In the construction of torpedo boats it appears that it is an easy matter to obtain speed without steering power, or steering power without speed; but to combine the two qualities has always been difficult. Messrs. Yarrow have attained a great success in this No. 79. As a general description of the boat, it may be said that she is fitted with two turrets, from either of which she may be steered. Working round each turret are two torpedo guns for firing over the side of the vessel, and there is also one torpedo gun forward for firing directly ahead. The boiler is of the ordinary torpedo-boat type, constructed for a working pressure of 240 pounds, and the engines are of the direct-acting inverted type, with three cylinders, making 400 revolutions per minute when working at full speed. The coal bunkers are capable of carrying sufficient coal for steaming 1800 miles at eleven knots per hour.

JANUARY 1, 1887. Naval summary of 1886. The defense of London. Military engineering. Improvements in ship ventilation, by Mr. Robert Boyle.

The German journal, *St. Hubertus*, gives a description of experiments made by the 3d Battalion of Jäger at Lübben in the training of dogs for war. The dogs are for the most part shepherd's dogs. Each company possesses two dogs. They are trained to run between the advanced posts and the main body of the battalion, and *vice versa*.

The Impérieuse has been deprived of her heavy and cumbrous masts and spars, as the result of her experimental trial at sea. This change, besides raising her armor belt and torpedo ports higher out of water, will probably enable her to realize the seventeen-knot speed for which she was designed.

JANUARY 8. "Our Navy—The Official View. Remarks by Lord Charles Beresford." Admiral Sir Thomas Symonds' view of the Navy.

A Fleet circular gives notice that vessels proceeding to or employed on the following stations—viz.: China, East Indies, and West Coast of Africa—are to be painted white. The cruiser Archer made a four hours' full-speed trial at Devonport recently. The results were: Draught of water forward, twelve feet three inches; aft, fourteen feet seven inches; revolutions of engine, 133; pressure of steam in cylinders, high, forty-one pounds; low, 13.7 pounds; vacuum in condensers, 25.5 inches; indicated horse power, high, 1032; low, 1187; total, 2219, being over the contract. Speed of ship by patent log, 15.52 knots. This trial was very satisfactory. The Archer is built of steel, is 225 feet long, thirty-six feet beam, and has a displacement of 1630 tons. She hastwin screws.

The Cossack, a steel cruiser of the same class as the Archer, was taken outside Plymouth Breakwater on Saturday, January 1, 1887, for trials of machinery and speed under forced draught. The draught of water forward was 12 feet 6 inches; aft, 14 feet 7 inches; pressure of steam in boilers, 118 pounds. Starboard engine—Pressure of steam in cylinders, high, 60.5 pounds; low, 20.6 pounds; vacuum in condenser, 24 inches; revolutions of engines, 155; indicated horse power, high, 894; low, 1045; total starboard engine, 1939. Port engine—Pressure of steam in cylinders, high, 61.0 pounds; low, 21.8 pounds; vacuum in condensers, 26 inches; revolutions of engines, 158.5; indicated horse power, high, 922; low, 1130; total port engines, 2052; tota. power of both engines, 3991; speed of ship by patent log, 17.8 knots. This was the result of the first two hours. At the end of the third hour some of the boiler tubes became leaky and the trial was discontinued.

On Monday, January 3, the Brisk, a steel cruiser of the same class as the Archer and Cossack, was taken outside the breakwater, Plymouth, for a four hours' full-speed trial under natural draught. Ballast was placed on board to bring the vessel's draught down to seagoing trim, which was 12 feet 6 inches forward, 14 feet 7 inches aft. The steam in the boilers was 116 pounds. Starboard engine—Pressure of steam in cylinders, high, 45.1 pounds; low, 16.0 pounds; vacuum in condensers, 24 inches; revolutions of engines, 137.8; indicated horse power, high, 593; low, 721; total, 1314. Port engines—Pressure of steam in cylinders, high, 45.2 pounds; low, 15.8 pounds; vacuum in cylinder, 24.3 inches; revolutions of engines, 137.2; indicated horse power, high, 592; low, 711; total, 1303; total both engines, 2617; speed of ship by patent log, 15.75 knots. The result was considered highly satisfactory.

On Tuesday, January 4, 1887, the Thames, a vessel similar to the Naniwa-kan, was taken outside Plymouth Breakwater for a preliminary trial of her machinery. The vessel is 300 feet long between perpendiculars, with moulded breadth of 46 feet. At the time of this trial her draught was—Forward, 13 feet 5 inches; aft, 17 feet 3 inches. A short trial was made to test her speed and power under

natural draught. The following was the result: Steam in boilers, 90 pounds. Starboard engine—Pressure of steam in cylinders, high, 45.2 pounds; low, 17.2 pounds; vacuum in condensers, 24.5 inches; revolution of engines, 108.2; indicated horse power, high, 1027; low, 1139; total starboard engine, 2166. Port engine—Pressure of steam in cylinders, high, 51.0 pounds; low, 17.3 pounds; vacuum in condensers, 24.5 inches; revolutions of engines, 110.3; indicated horse power, high, 1181; low, 1148; total for port engine, 2329; making a total for both engines of 4495, being 695 over the stipulated contract. The speed of the ship was 17 knots. The result was satisfactory.

B. F. T.

# Additional Note for No. 40.

## The Money Value of a Saving in Weight in the Armament of a War Vessel.

Where only about 6 per cent. of a ship's displacement is allotted to her armament the reduction of the weight of the guns becomes very important, and it will be interesting to endeavor to estimate the reduction in the value of a completely equipped ship owing to a saving in the weight of the guns.

In General Information Series, No. 5, of the office of naval intelligence is the translation of a paper by Mr. J. Normand, in which it is shown (p. 163) that in designing a vessel an increase, $k$, in the weight of any given object on board necessitates an increase in the ship's displacement of nearly $5\,k$ in order to retain the same speed, coal endurance, and other nautical qualities.

If we increase the weight of a gun by one ton we must increase the weight of its carriage by about two-thirds of a ton in order that the latter may stand the increased size of the gun, and the consequent increase in the ship's displacement would be—

$$5 \times 1\tfrac{2}{3} = 8\tfrac{1}{3} \text{ tons.}$$

Unarmored high-power ships, such as the "Baltimore," cost about $300 per ton for hull and engines, and therefore an increase of one ton in the weight of the guns would require an increase in the cost of such ships of $2,500.

If we grant that by employing a greater weight of a weaker material we can make cheap guns as trustworthy and as powerful as those now designed, it does not follow that this would be a real economy when the increased cost of the completed ship is considered.

Our present steel 8-inch guns cost, I believe, about $15,000.

or $1,200 per ton. Let us see what must be the maximum price of a weaker material, requiring 10 per cent. greater weight, which would justify us in employing it.

Let $a$ be the weight of the present gun, whose cost is $1,200 per ton.

Let $y$ be the cost per ton of the weak gun.

Let $m$ be the increased weight of the carriage in order to carry 10 per cent. additional weight.

Let $s$ be the cost per ton of the carriage.

The maximum cost per ton of the weak gun consistent with economy is then furnished by the equation—

$$11\,ay + 2{,}500\,a + ms = 10\,a \times 1{,}200.$$

As the weight of the carriage is about two-thirds that of its gun, we have $m = \frac{2}{3}\,a$, and hence, dividing by $a$, the equation becomes—

$$11\,y + 2{,}500 + \tfrac{2}{3}\,s = 12{,}000 \quad (1).$$

The 8-inch carriage for the "Atlanta" costs about $14,000, or about $1,550 per ton; so equation (1) becomes—

$$11\,y + 2{,}500 + \tfrac{2}{3}\,.1550 = 12{,}000;$$

Or—

$$11\,y = 8{,}467.$$

Or the cost of the weak material must be less than $770 per ton for real economy.

If the cheap material requires an increase in weight of 20 per cent. we shall find the limiting price to be $411 per ton.

When it is borne in mind that in a built-up gun the greater part of its cost is owing to labor and not to the first cost of material, it is evident that it is false economy to substitute mild steel for higher steel unless the resulting guns are as powerful, weight for weight.

WILLIAM LEDYARD RODGERS,
*Ensign, U. S. Navy.*